EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards), 2014. Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (Salmonella Yersinia, Shigella and Norovirus in bulb and stem vegetables, and carrots)

EFSA Publication

Link to article, DOI:
10.2903/j.efsa.2014.3937

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

European Food Safety Authority

EFSA Journal 2014;12(12):3937

SCIENTIFIC OPINION

Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (*Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables, and carrots)[1]

EFSA Panel on Biological Hazards (BIOHAZ)[2,3]

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ABSTRACT

Bulb and stem vegetables as well as carrots may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, cutting, packaging and storage. Risk factors for the contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus were considered in the context of the whole food chain. Available estimates of their occurrence in these vegetables were evaluated together with mitigation options relating to prevention of contamination and the relevance of microbiological criteria. Emphasis is given to vegetable types associated with public health risks, i.e. carrots, onion and garlic. It was concluded that each farm environment represents a unique combination of risk factors that can influence the occurrence and persistence of pathogens in the primary production of these vegetables. Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objectives of producers of bulb and stem vegetables as well as carrots. Considering the limited evidence for both the occurrence and public health risks from contamination of *Salmonella, Shigella, Yersinia* and Norovirus in the primary production and minimal processing of bulb and stem vegetables and carrots, no conclusions can be made on the impact of the establishment of microbiological Hygiene Criteria, Process Hygiene Criteria or Food Safety Criteria on public health. There is a lack of data on the occurrence and levels of *Escherichia coli* in bulb and stem vegetables as well as carrots. Thus, the effectiveness of *E. coli* criteria to verify compliance to GAP, GHP, GMP and food safety management systems (including HACCP) in the production and minimal processing of bulb and stem vegetables as well as carrots cannot be assessed.

KEY WORDS

bulb and stem vegetables, carrots, microbiological risk factors, Norovirus, *Salmonella, Shigella, Yersinia*

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Suggested citation: EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards), 2014. Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (*Salmonella Yersinia*, *Shigella* and Norovirus in bulb and stem vegetables, and carrots). EFSA Journal 2014;12(12):3937, 91 pp. doi:10.2903/j.efsa.2014.3937

Available online: www.efsa.europa.eu/efsajournal

SUMMARY

The European Commission asked EFSA's Panel on Biological Hazards (BIOHAZ Panel) to prepare a scientific opinion on the public health risk posed by pathogens that may contaminate food of non-animal origin (FoNAO). The outcomes of the first and second terms of reference, addressed in a previous opinion, were discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other three terms of reference. This is the final opinion out of five and addresses the risk from *Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables, and carrots. The terms of reference are to: (i) identify the main risk factors for bulb and stem vegetables, and carrots, including agricultural production systems, origin and further processing; (ii) recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables, and carrots, and (iii) recommend, if considered relevant, microbiological criteria for *Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables, and carrots.

Bulb and stem vegetables, for the scope of this opinion, are defined according to commercial production and consumption and correspond to the botanically true bulbs of onions (*Allium cepa* L., *Allium fistulosum* L.), shallot (*Allium cepa* L.), the composite bulb of garlic (*Allium sativum* L.); the bundle of leaf sheath of the leek (*Allium ampeloprasum* L.); the bulb-like fleshy petioles bases of the Florence fennel (*Foeniculum vulgare* Mill.); the young shoots of asparagus (*Asparagus officinalis* L.); the fleshy petiole of celery (*Apium graveolens* L.). Carrots (*Daucus carota* L.), for the scope of this opinion, are defined according to commercial production and consumption as a root vegetable, commonly orange. Emphasis is given here to vegetable types associated with public health risks, i.e. carrots, onion and garlic.

Bulb and stem vegetables as well as carrots may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, cutting, packaging and storage. Other types of minimal processing (e.g. commercial unpasteurized juicing) rarely occur outside retail and catering. Freezing may take place, but this will typically involve a heat blanching process and is outside the scope of this opinion, although frozen sliced onion may not be blanched. Bulb and stem vegetables as well as carrots may be subject to cooking, drying, bottling, canning and other processes but these are also outside the scope of this opinion.

Despite the variety of types of bulb and stem vegetables as well as carrots produced and consumed, there is very little or no specific information for interactions with, risk factors, mitigation options and occurrence of *Salmonella, Yersinia, Shigella* or Norovirus. Most information is available for *Salmonella* and carrots, although this is very limited. Consequently, in addition to the limited data, conclusions are drawn through what is generally understood about the properties of these pathogens as well as information from other fresh produce.

Onion, garlic and carrots grow in the soil and stem vegetables such as celery have prolonged direct contact with soil during growth and/or harvesting, particularly when celery is blanched. When consumed as ready-to-eat or minimally processed products, these vegetables are normally not subjected to physical interventions that will eliminate the occurrence of these pathogens.

For the identification of the main risk factors for *Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables and carrots, including agricultural production systems, origin and further processing, the BIOHAZ Panel concluded that the risk factors at primary production for the contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus are poorly documented in the literature, with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce: (1) environmental factors, in particular proximity to animal-rearing operation and climatic conditions that increase the transfer to pathogens from their reservoirs to the bulb and stem vegetables and carrot growing areas; (2) animal reservoirs (domestic or wild life) gaining access to growing areas for bulb and stem vegetables or carrots; (3) contamination or cross-contamination by equipment at harvest or post-

harvest, and by manipulation by workers if this takes place at primary production; (4) use of untreated or insufficiently treated organic amendments, and (5) use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as pesticides.

Processes at primary production which wet the external portions of the crop close to harvest represent the highest risk and these include spraying prior to harvest, direct application of fungicides and other agricultural chemicals and overhead irrigation.

During minimal processing, contamination or cross-contamination via equipment, water or food handlers are likely to be the main risk factors for contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus. There is limited information on the behaviours of *Salmonella, Yersinia, Shigella* or Norovirus in the specific vegetable food matrices but these pathogens are likely to survive on the surfaces of these vegetables for days to several weeks at both ambient and at refrigeration temperatures.

At distribution, retail and catering and in domestic and commercial environments, contamination and cross-contamination, in particular via direct or indirect contact between raw contaminated food and bulb and stem vegetables is a risk factor for *Salmonella, Yersinia, Shigella* and Norovirus. At distribution, retail, catering and in domestic or commercial environments, infected food handlers are also risk factors (particularly for Norovirus and *Shigella*). Contamination can be direct or indirect via poor hand hygiene or food contact surfaces. These contamination and cross-contamination risks include salad bar environments.

For the recommendation of possible specific mitigation options and the assessment of their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella, Yersinia, Shigella* and Norovirus in bulb and stem vegetables, and carrots, the BIOHAZ Panel concluded that appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing bulb and stem vegetables as well as carrots. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of microbiological hazards.

Salmonella have their reservoirs in domestic as well as wild animals, birds and humans. The main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots are consequently to prevent direct contact with animal, bird or human faeces as well as indirect contact through slurries, sewage, sewage sludge, contaminated soil, water, equipment or food contact surfaces or food handlers. *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* have their reservoirs in the intestinal contents of a range of animals and are commonly isolated from different environments contaminated by faeces. The main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots by *Yersinia* are consequently to prevent direct contact with animal or human faeces as well as indirect contact through slurries, sewage, sewage sludge, contaminated soil, water, equipment or food contact surfaces as well as food handlers. Both Norovirus and *Shigella* have their reservoir in humans. Therefore, the main mitigation options are good personal hygiene practices by food handlers during harvest, manual handling during sorting, packing and at the point of final preparation and food service. In addition, mitigation options include prevention of contamination from other food types as well as food contact surfaces.

The main sources within the environment from which contamination of food by Norovirus or *Shigella* can arise include sewage-contaminated water and sewage sludge. Hence, at primary production avoiding the use of sewage-contaminated water and inadequately treated sewage sludge, are the main mitigation options for reducing the risk of Norovirus and *Shigella* contamination of these vegetables.

Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, in the event of

heavy rainfall and flooding for example, intervention strategies should be applied to restrict growers from using this land for production of these vegetables until the hazards have been addressed. Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near bulb and stem vegetables as well as carrot growing areas. Attention should be paid to the selection of the water sources for irrigation, agricultural chemical application (e.g. fungicide) and in particular to the avoidance of the use or the ingress of water contaminated by sewage. Both water treatment or efficient drainage systems that take up excess overflows are possible mitigation options to prevent the additional dissemination of contaminated water. Risks posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm for the presence of pathogens. Since *Escherichia coli* is an indicator micro-organism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures. Appropriate production, treatment, storage, management and use of manure or sludge is important.

During minimal processing, GMP and food safety management systems (including HACCP) will assist *Salmonella, Yersinia, Shigella* and Norovirus risk mitigation strategies. It is recommended that water used during minimal processing be monitored to assess its microbial quality. When disinfectants are used in wash water the concentration should be monitored to verify that they are applied effectively to reduce the potential risk of cross-contamination while avoiding the accumulation of disinfection by-products.

The main mitigation options for reducing the risk of pathogen contamination of bulb and stem vegetables and carrots during minimal processing includes scrupulous adherence to hand hygiene by food handlers at all stages of the supply chain. Employees with symptoms of gastroenteritis should be excluded from working in food production (i.e. including harvesting and minimal processing) until their symptoms have subsided. Equipment should be cleaned and disinfected on a regular basis according to written procedures to ensure that the potential for cross-contamination is minimized. All persons involved in handling (cutting, grating, dicing, etc.) of bulb and stem vegetables as well as carrots for buffets in catering and restaurants should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

Information should be provided to consumers on appropriate handling of bulb and stem vegetables and carrots, which should include specific directions for product storage, preparation and intended use. Consumers should be informed if bulb and stem vegetables as well as carrots are intended to be consumed as ready-to-eat, and to wash and/or scrub whole or peeled products using potable running water when appropriate.

For the recommendation, if considered relevant, of microbiological criteria for *Salmonella, Yersinia, Shigella and* Norovirus in bulb and stem vegetables, and carrots throughout the production chain, the BIOHAZ Panel concluded that there is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Salmonella, Yersinia, Shigella and* Norovirus in the EU Member States and there are limited data on the occurrence of these pathogens in/on these vegetables in Europe. There are limited studies available in the peer-reviewed world literature on the occurrence of *Salmonella, Yersinia, Shigella and* Norovirus on/in bulb and stem vegetables as well as carrots. There are difficulties in making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

Considering the limited evidence for both the occurrence and public health risks from contamination of *Salmonella, Shigella, Yersinia* and Norovirus in the primary production and minimal processing of bulb and stem vegetables and carrots, no conclusions can be made on the impact of the establishment of microbiological Hygiene Criteria, Process Hygiene Criteria or Food Safety Criteria on public health.

There is a lack of data on the occurrence and levels of *E. coli* in bulb and stem vegetables as well as carrots. Thus, the effectiveness of *E. coli* criteria to verify compliance to GAP, GHP, GMP and food safety management systems (including HACCP) in the production and minimal processing of bulb and stem vegetables as well as carrots cannot be assessed.

The BIOHAZ Panel recommended that: (1) more detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA's zoonoses database on occurrence and enumeration of foodborne pathogens; (2) if additional biological hazards or further public health risks are identified with the consumption of these categories of food of non-animal origin, risk assessment studies may be needed to inform the level of hazard control that should be achieved at different stages of the food chain. These studies should be supported by targeted surveys on the occurrence of foodborne pathogens in such vegetables at specific steps in the food chain to indicate the level of hazard control and efficacy of application of food safety management systems, including GAP, GHP, GMP and HACCP, that can be achieved and (3) further data should be collected to evaluate the suitability of microbiological (e.g. *E. coli)* indicators for relevant microbiological hazards in bulb and stem vegetables and carrots during their production and minimal processing.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

In May 2011 a major outbreak of Shiga toxin-producing *Escherichia coli* (STEC)[4] O104:H4 occurred in Germany. About 4,000 people were reported ill with symptoms and the outbreak resulted in the death of more than 56 people. Other countries reported a certain number of people becoming ill by the same strain, most of whom had recently visited the region of northern Germany where the outbreak occurred. At the end of June 2011, there was a second cluster in Bordeaux, France, which was caused by the same *Escherichia coli* strain. In both cases, investigations pointed to the direction of sprouted seeds.

According to the 2009 Zoonoses Report,[5] the majority of verified outbreaks in the EU were associated with foodstuffs of animal origin. Fruit and vegetables were implicated in 43 (4.4 %) verified outbreaks. These outbreaks were primarily caused by frozen raspberries contaminated with Norovirus.

According to the US Centers for Disease Control and Prevention (CDC) 2008 report on surveillance for food borne disease outbreaks,[6] the two main commodities associated with most of the outbreak-related illnesses originating from food of plant origin were fruits-nuts and vine-stalk vegetables. One of the main pathogen-commodity pair responsible for most of the outbreaks was Norovirus in leafy vegetables. The pathogen-commodity pairs responsible for most of the outbreak-related illnesses were *Salmonella* spp. in vine-stalk vegetables and *Salmonella* spp. in fruits-nuts. In addition, as recently as September 2011, a multistate outbreak of listeriosis linked to cantaloupe melons caused 29 deaths in the US.

Regulation (EC) No 852/2004 on the hygiene of foodstuffs[7] lays down general hygiene requirements to be respected by food businesses at all stages of the food chain. All food business operators have to comply with requirements for good hygiene practice in accordance with this Regulation, thus preventing the contamination of food of animal and of plant origin. Establishments other than primary producers and associated activities must implement procedures based on the Hazard Analysis and Critical Control Points (HACCP) principles to monitor effectively the risks.

In addition to the general hygiene rules, several microbiological criteria have been laid down in Regulation (EC) No 2073/2005[8] for food of non-animal origin.

Following the STEC O104:H4 outbreak in Germany and France, the Commission already has asked EFSA for a rapid opinion on seeds and sprouted seeds. EFSA adopted a scientific opinion on the risk posed by STEC and other pathogenic bacteria in seeds and sprouted seeds on 20 October 2011. The current mandate intends to supplement the adopted opinion.

In view of the above, there is a need to evaluate the need for specific control measures for certain food of non-animal origin, supplementing the general hygiene rules.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is asked to issue scientific opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin such as fruit, vegetables, juices, seeds, nuts, cereals, mushrooms, algae, herbs and spices and, in particular:

1. To compare the incidence of foodborne human cases linked to food of non-animal origin and foodborne cases linked to food of animal origin. This ToR should provide an indication of the

[4] Also known as Verocytotoxin-producing *Escherichia coli* (VTEC).
[5] EFSA Journal 2011;9(3):2090
[6] www.cdc.gov/mmwr/preview/mmwrhtml/mm6035a3.htm?s_cid=mm6035a3_w
[7] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.
[8] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

proportionality between these two groups as regard human cases and, if possible, human burden.

2. To identify and rank specific food/pathogen combinations most often linked to foodborne human cases originating from food of non-animal origin in the EU.

3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

4. To recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

The Commission would like an opinion on the first and second terms of reference by the end of December 2012. The outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference.

CLARIFICATIONS OF THE TERMS OF REFERENCE 3 TO 5 OF THE REQUEST ON THE RISK POSED BY PATHOGENS IN FOOD OF NON-ANIMAL ORIGIN

BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

On 23 January 2012, a request was provided to the European Food Safety Authority (EFSA) to issue scientific opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin (FoNAO).

The BIOHAZ Panel of EFSA adopted during its meeting on 6 December 2012 an opinion on the first and second terms of reference, focussing on

- the comparison of the incidence of foodborne human cases linked to FoNAO and foodborne cases linked to food of animal origin;

- identifying and ranking specific food/pathogen combinations most often linked to foodborne human cases originating from FoNAO in the EU.

It was agreed in the original request that the outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference addressing risk factors, mitigation options and possible microbiological criteria.

The first opinion of EFSA under this request identifies more than 20 food/pathogen combinations in its five top ranking groups. The opinion also contains a preliminary assessment of risk factors linked to certain examples of FoNAO (e.g. tomatoes, watermelons and lettuce), representing specific production methods for several FoNAO. Several risk factors and mitigation options may be common for several food/pathogen combinations due to similar production methods. It seems therefore opportune to combine the risk assessment of such food/pathogen combinations. When risk factors and mitigation options are identified as more specific to the individual food/pathogen combination, then these should be considered to supplement this approach and added where possible within the, opinions. Alternatively, it is worth mentioning that a reference could be made if such specific risks have already been addressed in previous opinions.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is asked, in accordance with article 29 of Regulation (EC) No 178/2002,[9] to provide scientific opinions on the public health risk posed by pathogens on food of non-animal origin as regards risk factors, mitigation options and possible microbiological criteria. When considered more appropriate e.g. because of low prevalence of the pathogen or in view of a broader process control, indicators may be proposed as Process Hygiene Criteria. When addressing mitigation options at primary production, attention should be paid to Article 5(3) of Regulation (EC) No 852/2004,[10] which laid down that the application of hazard analysis and critical control points (HACCP) principles shall only be applied to food business operators after primary production and associated activities.[11] This provision does, however, not exclude proposing microbiological criteria in accordance with terms of reference 5 when considered relevant.

EFSA is requested to provide opinions in line with the agreed terms of Reference 3 to 5 (EFSA-Q-2012-00237) for the following food/pathogen combinations with a similar production system:

(1) The risk from *Salmonella* and Norovirus in leafy greens eaten raw as salads.
Cutting and mixing before placing on the market should be included as potential risk factor and specific mitigation options proposed if relevant.

(2) The risk from *Salmonella*, *Yersinia*, *Shigella* and Norovirus in bulb and stem vegetables, and carrots.

(3) The risk from *Salmonella* and Norovirus in tomatoes.

(4) The risk from *Salmonella* in melons.

(5) The risk from *Salmonella* and Norovirus in berries.

[9] OJ L 31, 1.2.2002, p.1
[10] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs.
[11] See guidance at: http://ec.europa.eu/food/food/biosafety/hygienelegislation/guidance_doc_852-2004_en.pdf

ASSESSMENT

1. Introduction

Bulb and stem vegetables as well as carrots can be consumed as minimally processed, ready-to-eat food, which are widely eaten and usually free from noxious substances such as poisonous chemicals, toxins and pathogenic micro-organisms. However, a previous EFSA opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013a), carried out a risk ranking exercise for identifying the relative importance of combinations of food of non-animal origin (FoNAO) and pathogens linked to outbreaks of foodborne illness in the EU. Leafy greens eaten raw as salads and *Salmonella* were ranked as the most important (EFSA Panel on Biological Hazards (BIOHAZ), 2013a), but this analysis ranked the combination of: bulb and stem vegetables together with *Salmonella* as amongst the second most important combinations, together with bulb and stem vegetables and Norovirus as one of the fourth most important combinations. Furthermore, the same analysis (EFSA Panel on Biological Hazards (BIOHAZ), 2013a) risk ranked the combinations of carrots both with *Yersinia* as amongst the fourth most important, and with *Shigella* as one of the fifth most important groups.

The main risk factors for microbiological risks, together with their mitigation options, are applicable to many points in the food chain for bulb and stem vegetables and carrots. However since the supply chains of bulb and stem vegetables and carrots may not include processing steps or control points which will ensure inactivation or removal of biological hazards, it is particularly important to consider risk factors (and consequentially mitigation options) at the point of production, (minimal) processing, storage and retail or catering. This is similar to other foods of non-animal origin, which are minimally processed and often sold as ready-to-eat, as well as with some foods of animal origin (e.g. unpasteurised dairy products, shellfish and meats), which are also eaten raw or minimally processed.

The approaches used in this opinion are:

1. To provide a descriptive analysis of the whole production process for a representative range of bulb and stem vegetables and carrots which considers their origins in agricultural production, growing, harvesting, minimal processing, distribution, retail, catering and handling in domestic environments. Emphasis will be given to descriptions of vegetable types associated with public health risks. Risk factors for contamination by *Salmonella, Yersinia, Shigella* and Norovirus are considered in the context of the agricultural production, minimal processing, distribution and retail/catering/domestic environments. In discussions with the European Commission it was agreed that for all the FoNAO considered in this and the related opinions, only minimally processed products are considered (which includes cutting, washing, peeling, shredding, freezing, mashing and unpasteurized juicing). Products undergoing thermal treatments (including heat blanching as well as shelf-stable juicing) and other processing treatments (such as pickling, canning, bottling, drying or powdering), as well as composite foods containing these vegetables are not considered in the scope of these opinions.

2. This opinion includes separate Sections, which assess specific mitigation options to reduce contamination of bulb and stem vegetables and carrots by *Salmonella, Yersinia, Shigella* and Norovirus which reduces the risk of exposure through food consumption. Assessment of the mitigations options is performed in a qualitative manner similar to that performed for the scientific opinion on the risk posed by Shiga toxin-producing *Escherichia coli* (STEC) and other pathogenic bacteria in seeds and sprouted seeds (EFSA Panel on Biological Hazards (BIOHAZ), 2011c), and include consideration of generic mitigation options previously identified for leafy greens eaten raw as salads (EFSA BIOHAZ Panel, 2014a), berries (EFSA BIOHAZ Panel, 2014b), melons (EFSA BIOHAZ Panel, 2014e) and tomatoes (EFSA BIOHAZ Panel, 2014d). Emphasis is given here to vegetable types associated with public health risks, i.e. carrots, onion and garlic.

3. Sampling and analytical methods for the detection of *Salmonella, Yersinia, Shigella* and Norovirus (together with the use of *E. coli* as an indicator organism) in bulb and stem vegetables and carrots are considered similarly to those identified for leafy greens (EFSA BIOHAZ Panel, 2014a) berries (EFSA BIOHAZ Panel, 2014b), melons (EFSA BIOHAZ Panel, 2014e) and tomatoes (EFSA BIOHAZ Panel, 2014d). Summaries of available data on estimates of occurrence for *Salmonella, Yersinia, Shigella*, *E. coli* and Norovirus in bulb and stem vegetables and carrots are presented. The relevance of microbiological criteria applicable to production, minimal processing and at retail/catering was considered. Microbiological criteria in domestic settings were not considered.

1.1. Public health risks associated with bulb and stem vegetables as well as carrots

Previous risk ranking analysis used data from foodborne outbreaks reported as part of the zoonoses monitoring (Directive 2003/99/EC)[12] in the EU between 2007 and 2011 (EFSA Panel on Biological Hazards (BIOHAZ), 2013a). Outbreaks having a strong or moderate strength of association with consumption of raw or minimally processed bulb or stem vegetables or carrots were as follows:

- Carrots and
    - *Yersinia pseudotuberculosis,* 2008, Finland, 50 cases
    - *Shigella,* 2008, Sweden, 145 cases
    - Norovirus, 2009, Belgium, 2 cases
- Onion and
    - *Salmonella enterica* serovar Haifa, 2011, Sweden, 30 cases
    - Norovirus, 2011, Finland, 16 cases
- Garlic (water used for brushing langos) and
    - Norovirus, 2010, Germany, 2 cases

Some of the above outbreaks are further documented in the peer-reviewed literature: carrots contaminated with *Y. pseudotuberculosis* (Kangas et al., 2008; Vasala et al., 2014) and carrots contaminated with Norovirus (Kaminska et al., 2014). Additional information is available for outbreaks in the EU which occurred outside the previous 2007-2011 study period (EFSA Panel on Biological Hazards (BIOHAZ), 2013a) and were associated with: *Y. pseudotuberculosis* infection and consumption of grated carrots which occurred in 2003 and 2006 (111 and > 400 cases respectively (Jalava et al., 2006; Rimhanen-Finne et al., 2009); and Norovirus and frozen carrots in 2012, Poland, 97 cases (Kaminska et al., 2014); four Norovirus outbreaks associated with consumption of carrots (one outbreak of 122 cases in Sweden in 2012; and the remaining three outbreaks in Germany in 2012 and 2013 with 2, 2, and 5 cases respectively).

In addition, an outbreak has been reported within the EU with these types of food products and other biological hazards, namely: grated carrots with red peppers and *Cryptosporidium hominis* in Denmark (Ethelberg et al., 2009). Outbreaks have been reported with these types of food products outside the EU and included: enterotoxigenic *E. coli* and chives in Norway (Macdonald et al., 2014); spring onion (also known as scallions or green onions) and hepatitis A virus in the USA (Dentinger et al., 2001; Wheeler et al., 2005); diced celery and *Listeria monocytogenes* in the USA (Gaul et al., 2013); raw

[12] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

carrots and *Shigella sonnei* in the USA (Gaynor et al., 2009); carrots and *Salmonella enterica* serovars Branderup and Typhimurium in the USA (Hanning et al., 2009); raw celery and Norovirus in the USA (Warner et al., 1991); raw celery/tomatoes/lettuce and *Listeria monocytogenes* in the USA (Ho et al., 1986); and fresh garlic and *Salmonella enterica* serovar Virchow in Australia (Bennett et al., 2003).

In consultation with the European Commission and, based on documented public health risks, the approach used in this opinion will focus on descriptions of production systems, risk factors and mitigation options for the foods and pathogens outlined in Table 1 from EFSA Panel on Biological Hazards (BIOHAZ) (2013a). Other bulb and stem vegetable types will be briefly considered if these have been associated with public health risks. This approach allows more general recommendations covering similar production cycles, risk factors and mitigation options for this group of vegetables consumed raw or minimally processed.

Table 1: Food pathogen combinations identified in EFSA Panel on Biological Hazards (BIOHAZ) (2013a) based on strong or moderate associations with foodborne outbreak data reported in the EU from 2007 to 2011 associated with raw or minimally processed bulb and stem vegetables and carrots

Pathogen	Food vehicle[(a)]	Setting[(b)]	Place of origin of problem[(c)]	Contributory factors[(d)]
Salmonella enterica serovar Haifa	Onion	Disseminated cases	Unknown	Unprocessed contaminated ingredient
Yersinia pseudotuberculosis	Raw grated carrot	School kindergarten	Farm (primary production)	Unprocessed contaminated ingredient
Shigella	Raw grated carrots	Restaurant, cafe, pub, bar, hotel	Catering services, restaurant	Infected food handler
Norovirus	Garlic water used for brushing lángos	Restaurant, cafe, pub, bar, hotel	Restaurant, cafe, pub, bar, hotel, catering services	Cross-contamination, infected food handler, unprocessed contaminated ingredient
Norovirus	Chopped onion	Household, domestic kitchen	Restaurant, cafe, pub, bar, hotel, catering services	Infected food handler
Norovirus	Carrots	Residential institution (nursing home, prison, boarding school)	Catering services, restaurant	Not reported

(a): Available information reported on the food vehicle.
(b): Place of exposure to the food vehicle. This is the location where the food was consumed or where the final stages of preparation of the food vehicle took place (e.g. café/restaurant, institution, home, take-away outlet).
(c): Place, other than setting, where the mishandling of the food took place and/or where the contamination occurred.
(d): Contributing factors are factors that contributed to the occurrence of the foodborne outbreak. These may include deficiencies in food handling or contaminated raw materials.

2. Production of bulb and stem vegetables and carrots

2.1. Definition of bulb and stem vegetables and carrots

True bulbs are normally formed underground on the basis of modified leaves, consisting of a succession of layers of scales surrounding the sprout. The scales occur on a very short, compacted stem, the "stem plate" on which are attached the roots. These vegetables include a high diversity of products and the size, shape and colour can vary depending on the species of plant and cultivar. Bulbs are usually produced by biannual plants which enter into dormancy during the winter. Some plants, such as onion or garlic, can also produce aerial small bulbs. Only bulbs and vegetables consumed raw or minimally processed are considered here.

Bulb and stem vegetables for the scope of this opinion, are defined according to commercial production and consumption and correspond to the botanically true bulbs of onions (*Allium cepa* L., *Allium fistulosum* L.), shallots (*Allium cepa* L.), the composite bulb of garlic (*Allium sativum* L.); the bundle of leaf sheath of leek (*Allium ampeloprasum* L.); the bulb-like fleshy petiole bases of the Florence fennel (*Foeniculum vulgare* Mill.); the young shoots of asparagus (*Asparagus officinalis* L.); and the fleshy petiole of celery (*Apium graveolens* L.).

Carrots (*Daucus carota* L.), for the scope of this scientific opinion, are defined according to commercial production and consumption as a root vegetable which is commonly orange, although others colours such as purple, red, white and yellow occur. The edible part of the carrots is developed underground and includes the root. Carrots are storage organs, principally of carbohydrates. They generally have low respiration rates although it will depend on the stage of development. Thus, they are considered relatively non-perishable, especially if the tops are removed. Carrots will continue growing after harvest (rooting and sprouting); and can be stored for relatively long periods. Only carrots consumed raw or minimally processed are considered here.

Bulb and stem vegetables were previously defined to include: asparagus, cardoon, celeriac, celery, elephant garlic, Florence fennel, garlic, kohlrabi, kurrat, leek, lotus root, nopal, onion, Prussian asparagus, shallot, spring onion and welsh onion (EFSA Panel on Biological Hazards (BIOHAZ), 2013a).

Carrots were previously defined to include: baby carrots, carrot coins, (unpasteurised) juice, sticks, grated, shredded and sliced carrots (EFSA Panel on Biological Hazards (BIOHAZ), 2013a).

Onions cover a wide diversity of different produce, and for this opinion, are classified according to the production season and day length required to initiate bulb formation, as long-day, short-day, or intermediate-day types (UK cooperative extension service, 2013). For market considerations, onions are also classified according to their colour (white or red bulbs), taste (having pungent or sweet flavours) and shape (with globes, elongated globes, spindle, flat, yellow) (UK cooperative extension service, 2013; UGA extension, 2014). For the purpose of this opinion, two main categories will be considered.

- Onions produced as mature bulbs, covered with dry papery leaves (also called scales or skins), which can usually be stored for several months. A wide range of cultivars is used, including yellow, red, white, sweet onions (UK cooperative extension service, 2013). All these cultivars belong to the species *Allium cepa* L.

- Onions produced as immature bulbs attached to fresh tubular leaves. Bulbs can be of various sizes, and are fully formed to very slender (Chambre d'Agriculture Lot-et-Garonne, 2010). They are sold under different names such as green onions, spring onions, salad onions, welsh onion, scallions, and are usually presented at retail sale as bunches. The cultivars used to produce these immature bulbs can belong to *Allium cepa* L., the same species as used to

produce mature onions, and in such cases are harvested at an early stage. Alternatively, other onion species can be grown for this use, i.e. *Allium fistulosum* L. (Oregon State University, 2002a; Ariyama and Yasui, 2006). Chives (*Allium schoenoprasum* L.*)* are the smallest onion type consumed and only the leaves are used, however these are out of scope for this opinion as these were previously categorised as a fresh herb (EFSA Panel on Biological Hazards (BIOHAZ), 2013a).

All types of onions can be eaten without cooking, although this is most common for green onions and sweet cultivars of mature onions. With respect to this opinion, the most important distinction lies between mature onions and green (immature) onions. Leeks are also occasionally consumed raw or minimally processed.

Garlic bulbs are formed of 5-20 "cloves" each representing a bud (or a small bulb) formed of 2 scales, one outside scale which is dry and papery, one internal fleshy scales containing water and nutrients for the sprout. Garlic represents a less diverse product than onions (Larousse Agricole, 2002). The main differences are autumn cultivars (planted in autumn) and spring cultivars (planted in end of winter-early spring). Spring cultivars produce smaller bulbs, which can be stored longer than autumn cultivars (Chambre d'Agriculture de la Haute-Garonne, 2004). Bulbs can be white (both types of cultivars), purple (autumn cultivars) or pink (spring cultivars) (Chambre d'Agriculture de la Haute-Garonne, 2004).

Commercially produced carrots usually consist of roots of deep orange colour. Nantes-type cultivars are commonly grown in Europe and have sparse foliage that is attached to the crown of this vegetable. The root is moderately long (usually 15 and 20 cm), with a uniform diameter along the length and a rounded tip when mature (CALU, 2007). The surface is thin and easily damaged. The highly pigmented core is poorly developed making roots brittle. Nantes cultivar is the most common type used for the fresh-cut minimal processing (Appendix A, Freshfel information). The Nantes cultivar is less suitable for long-term storage than other cultivars such as Chantenay and Danvers owing to the fact that roots have higher sugar content, lower in terpenoids and lower dry matter (Appendix A, Freshfel information).

Bulb and stem vegetables as well as carrots can be consumed after processing (cooking, pickling, pasteurised juicing, drying etc.), but these are out of the scope of this opinion. These vegetables are also consumed as whole or as fresh-cut products (including those sliced, diced and grated). Fresh juices may also be prepared for immediate consumption (see Section 6). Despite the variety of types of bulb and stem vegetables as well as carrots produced and consumed, there is very little or no specific information for interactions with risk factors, mitigation options and occurrence of, *Salmonella, Yersinia, Shigella* or Norovirus. Most information is available for *Salmonella* and carrots, although this is very limited. Consequently, in addition to the limited data, conclusions are drawn from what is generally understood about the properties of these pathogens as well as information from other fresh produce.

Celery has been associated with foodborne outbreaks in the USA (Ho et al., 1986; Warner et al., 1991) and will be used to describe additional production systems for bulb and stem vegetables other than those listed in Table 1. The aerial organ of celery is consumed (although this is often blanched by covering with soil), and is different from mature onion, garlic and carrots where the edible portions grow within or on the surface of the soil. Among bulb and stem vegetables, celery will illustrate the case of "stem vegetables", although what is currently called the celery "stem" or "stalk" is botanically made up of leaves and petioles.

2.2. Description of production systems: carrots

Carrots are a cool-season crop, but will tolerate warm temperatures early in the growing season. Roots attain optimal colour when the air temperature is 18 to 21 ºC (Nunez et al., 2008). Root colour can deepen rapidly when temperatures are within this range 3 weeks before harvest. Above 30 ºC, the

growth of foliage is reduced and strong flavours develop in the roots, reducing their market quality. Below 10 ºC, carrot roots and foliage grow slowly. Carrots tolerate some frost (Nunez et al., 2008).

2.2.1. Seed and seedling production

Carrots are always directly seeded in soil. Both raw and pelleted seeds are used (Nunez et al., 2008). The ideal sowing time is March/April, about 2 weeks before the last frost is expected. However, it is possible to establish a "forced crop" which is sown as early as February using cold frames or cloches for protection. If sown in October, a fleece or plastic cover is needed over winter (CALU, 2007). In Europe, seeding is done mechanically. Usually, the seeds are sown in beds with sufficient water to allow growth (Appendix A, Freshfel information). Between rows spacing is 15 to 30 cm with approx. 100 carrots per m^2. Higher densities are used for plantings for the fresh-cut market. When beds are used then more seeds should be placed on the outside rows of the beds. Seeds are sown about 2 cm deep with a precision drill. The ideal soil temperature for germination is 10 °C (CALU, 2007). Seed within a lot might vary significantly in size, maturity, vigour and germination time; emergence often occurs over several days (Nunez et al., 2008).

2.2.2. Open field production

The optimum soil types to grow carrots are clay-loamy soils, which provide the best combination of water-holding capacity and drainage, although carrots are also grown on sandy soils. Heavy soils can encourage hairy, deformed roots. Carrots can be successfully produced in both acid and alkaline soils. However, a pH above 6.0 has been recommended for successful establishment. The structure of the soil is also important (Appendix A, Freshfel information). It is recommended that the upper 75 cm of soil should be uniform and free of barriers to root growth (Nunez et al., 2008). To avoid getting forked roots, the soil should be stone-free for cultivation (CALU, 2007). Thus, the analysis of the soil is needed to determine its suitability (Appendix A, Freshfel information). Light, well-drained and peaty soils are ideal. High organic matter content is recommended but it should be ensured that farmyard manure is well composted and is applied a few months before planting to avoid getting forked roots.

As the carrot root matures, carotene accumulates, causing the root to change from yellow-white to yellow and then orange. Although cultivars differ in their potential for orange colour, soil fertility, temperature, and water content are the main factors influencing root colour. The health of the leaves plays a minor role in root colour unless the tops are severely stressed (Nunez et al., 2008).

It is important to maintain the levels of soil moisture because, if moisture levels decline and the root tops are exposed to the sun, carrots are vulnerable to "green shoulder" and develop a bitter taste. Covering with fleece or plastic covers or, traditionally, with straw might also be necessary as shelter when temperatures are low (CALU, 2007).

2.2.3. Water sources and irrigation systems

A uniform water supply is critical for good colour and root formation. If significant wet-dry cycles occur, the roots will split. Excessive watering discourages good colour formation and may encourage plant disease (Nunez et al., 2008). It has been established that carrots require 20-25 mm of rainfall per week during the growing season but under warm, dry conditions up to 50 mm will be required. Overhead systems or sprinkler lines are mainly used for irrigation if required (CALU, 2007). Therefore, fields have to be equipped with irrigation systems and the crop is irrigated lightly, immediately after sowing. Sometimes, irrigation is needed over the season from the sowing to the harvest (Appendix A, Freshfel information). Under warm, dry conditions, irrigation water should be applied once or twice a day. Watering should be gradually reduced to prevent longitudinal splitting of the roots when the crop approaches maturity. Water stress during root development also causes cracking of the roots, which also become hard.

2.2.4. Different types of fertilisation, organic/manure/compost

Growers use fertilizers and pesticides to increase the production yield (Appendix A, Freshfel information). Carrot is a comparatively deep-rooted crop compared to other vegetables, and is able to efficiently extract nitrogen from soil to a depth of several feet. Seasonal nitrogen application varies widely among growers and fields, ranging from as low as 110 kg/ha to 280 kg/ha. Research has shown that seasonal nitrogen rates greater than 170 kg/ha are seldom necessary to maximize root yield, and that excessive nitrogen application increases root cracking during harvest and handling (Nunez et al., 2008).

Fertiliser recommendations should be based on soil analyses. A small amount of nitrogen is typically applied before sowing with phosphorus fertilizer, with the majority of nitrogen applied either as a side dressing or through sprinkler irrigation (Nunez et al., 2008). Organic fertilizers can represent a source of foodborne pathogens if not adequately treated (EFSA BIOHAZ Panel, 2014c). Manure from various sources can be used but they should be applied a few months before sowing or planting, ideally with a different crop between manure application and carrot production.

2.2.5. Harvesting

To determine the optimum time for harvesting, growers take samples from different points of the plot, including from the leaves, to determine the maturity stage of the root: the leaf quality is an important parameter (Appendix A, Freshfel information). However, in most cases, harvest decisions for carrots are based on criteria depending on the market outlet or sales endpoint. Typically carrots are harvested at an immature state when the roots have achieved sufficient size to fill in the tip and develop a uniform taper. Length may be used as a maturity index for harvest timing of 'cut and peel' carrots to achieve a desired minimal processing efficiency (Suslow et al., 2002).

In Europe, almost all carrots are mechanically harvested. Commercially grown carrots are harvested using self-propelled multi-row harvesters (Nunez et al., 2008). Careful handling is necessary to avoid bruising or breaking the roots, thus avoiding mechanical damage. Harvest season is usually between September and October, but if harvest is carried out when the environment is too wet, it can be detrimental for quality (Appendix A, Freshfel information). To avoid exposing the roots to heat, harvesting it is often done after sunset. Also, it is not recommended to leave harvested carrots for too long on the field, as they will attract carrot fly (CALU, 2007).

2.2.6. Cooling/post-harvest storage

Carrots are harvest in September-November and they can be stored until the following June. As carrots can develop a 'rubbery' texture relatively easy it is necessary to store them below 5 °C. Cold storage is typically carried out at 2 ºC and 95 % relative humidity (RH) (Appendix A, Freshfel information). High relative humidity is essential to prevent desiccation and loss of crispness. However, common storage conditions rarely achieve the optimum temperature for long-term storage to prevent decay, sprouting, and wilting. At storage temperatures of 3-5 °C, mature carrots can be stored with minimal decay for 3-5 months (Suslow et al., 2002). In some parts of Europe carrots can be stored up to 9 months (Appendix A, Freshfel information).

To store carrots, green leaves are removed, however the soil remains on this vegetable. After storage, the soil is removed by dry brushing; carrots are washed and finally packed and sold to the consumers. When produced on a large scale, washing of the carrots after harvest is done in a washing line. The first step uses a washing bath where carrots are washed for up to 4 hours. The washing tank consists of a tank where the water is refreshed occasionally. After the washing tank, carrots are rinsed with shower water and go via a conveyor belt to packing. Carrots are not dried and are maintained as much as possible in water (Appendix A, Freshfel information). Careful handling of carrots during and after harvest prevents bruising, shatter-cracks, and tip breaks and prolongs storage life. Free moisture from the washing process or condensation, commonly obtained if stored within plastic bags, will promote vegetable decay (Suslow et al., 2002).

After washing, packed carrots can be successfully stored for a further 2-3 weeks at 3-5 °C. However, carrots can also be sold in bunches tied together including the shoots (CALU, 2007). Bunched carrots are highly perishable due to the presence of the shoots, but can be maintained for 8-12 days (Suslow et al., 2002).

Exposure to ethylene will induce the development of a bitter flavour due to isocoumarin formation. Exposure to as little as 0.5 ppm exogenous ethylene will result in a perceptible bitter flavour, within 2 weeks under normal storage conditions. Thus, carrots should not be mixed with ethylene-producing commodities such as apples, bananas, tomatoes etc. (Suslow et al., 2002).

2.3. Description of production systems: onions

2.3.1. Seed and seedling production

Sowing can be done with seeds or bulbils (small bulbs). Bulbils permit a more rapid growth of the plant but are restricted to fewer cultivars than seeds (LPC bio, 2013). Sowing is usually done from March to May with harvest from August to October, a later sowing and harvest being preferable for onions intended for a long storage (LPC bio, 2013). In "winter culture", sowing is done at the end of summer or in October and harvest in late spring or summer (Verolet, 2001; Chambre d'Agriculture Rhônes-Alpes, 2012). Seeds can also be sown to produce small plants, which are transplanted as soil balls (produced with 3-5 seeds per ball), frequently in soil covered by mulch or plastic lining to limit weeds development (Chambre d'Agriculture Rhônes-Alpes, 2012). Green onions are produced similarly with a shorter production cycle, with sowing or transplanting from March to July and harvesting from July to October. For "winter culture" green onions can be sown in September and harvested in April (Chambre d'Agriculture Rhônes-Alpes, 2012).

2.3.2. Open-field production

All types of onions can be grown in open fields. For mature onions, the soil must be prepared to obtain a uniform structure for the first 2-5 cm. Deep soil that retains water is preferred. Onion crops never fully cover the soil and are therefore very sensitive to weeds (UGA extension, 2014). Apart from chemical herbicides, several techniques are used to reduce or prevent the growth of weeds, including covering the growing areas before soil preparation for the onion crop, successions of delays and mechanical destruction of weeds before sowing or planting onions, application of heat before and after sowing or planting (Chambre d'Agriculture Rhônes-Alpes, 2012; LPC bio, 2013). The impact of these practices on the survival of foodborne pathogens present in the soil is not known.

2.3.3. Greenhouse production

Greenhouse production is particularly important to obtain green onions in winter (Civam Bio des Pyrénées-Orientales). Greenhouse production is less important for mature onions which are stored for several months and harvested from spring to autumn (using cultivars of different precocity and for which bulb formation is initiated for different day lengths). Greenhouse onion crops usually come from transplants. In an EU Mediterranean climate in unheated greenhouses for instance, the small plants (obtained from seeds in approximately one month) can be transplanted as soil balls covered by plastic lining from September to January and green onions harvested from the beginning of January to April. Greenhouses must be very well ventilated to avoid excess humidity, which will increase the risk of onion disease development (Civam Bio des Pyrénées-Orientales). The requirements concerning weeds control, fertilization and irrigation are the same as for open-field cultivation.

2.3.4. Water sources and irrigation systems

Onions need very well controlled water supplies, with high water requirements after transplantation to allow for leaf formation, and bulb enlargement. However, control of irrigation is also important to avoid the formation of persistently humid zones in the field. For these reasons, onion crops are usually irrigated, using sprinkler, furrow or drip irrigation (Verolet, 2001; LPC bio, 2013; UGA extension, 2014). Irrigation permits the production of less pungent, sweeter, onions (UGA extension, 2014). The

relative proportions of the various irrigation techniques and the sources of water in the EU are not documented. For mature onions, to improve storage ability of the bulb, irrigation is stopped between 1 and 3 weeks before harvest depending on climates and cultivars (Verolet, 2001; UGA extension, 2014). In contrast, for green onions, irrigation just before harvest facilitates pulling out of the plants from the soil (Chambre d'Agriculture Lot-et-Garonne, 2010).

2.3.5. Different types of fertilisation, organic/manure/compost

Onions are particularly demanding of fertilizers to allow adequate development of the aerial part of the plant as well as the bulb. However, excess or too late supply of nitrogen increases the risk of fungal disease and reduces storage (Verolet, 2001; LPC bio, 2013; UGA extension, 2014). Organic fertilizers may be a source of foodborne pathogens if not adequately treated (EFSA BIOHAZ Panel, 2014c). Manure of various sources can be used but should be applied a few months before sowing or planting of onions, ideally with a different crop between manure application and onion production (Chambre d'Agriculture Lot-et-Garonne, 2010; LPC bio, 2013). This represents an approximate delay between manure application and harvest of 1 year and 8-9 months for mature onions and for green onions, respectively. Organic fertilizer with rapid nutrient release (e.g. guano) can be used at and after sowing or planting, but should be stopped at the start of bulb formation (e.g. beginning of July). This could represent 1 to 3 months delay before harvest for mature onions, but with a shorter delay for green onions (Verolet, 2001; LPC bio, 2013).

2.3.6. Harvesting

Selection of the harvest date for mature onions is a compromise between yield, quality of the bulb and storage ability. An optimal harvest time is indicated by a soft neck (attachment of the leaves to the top of the bulb) and the leaves remaining green. At this stage, the bulbs need post-harvest mechanical drying. Later harvest provides drier bulbs but with an incompletely closed neck, frequent colonization by fungal soft rot agents, and with damaged external scales (Chambre d'Agriculture Rhônes-Alpes, 2011; UGA extension, 2014). Bulbs are pulled out, usually mechanically and in dry weather conditions, then left in the field for 3 to 10 days, depending on the type of onions, for pre-drying (Chambre d'Agriculture Rhônes-Alpes, 2011; UGA extension, 2014).

For green onions with bulbs (as well as scallions or welsh onions), the harvest should begin when bulbs are 2-4 cm in diameter, although green onions are also sold without formed bulbs and with only a white 'shank' at the base of the leaves (Civam Bio des Pyrénées-Orientales). Onions are pulled out usually manually, sometimes with the help of an undercutting tool (NC State University, 2001; Civam Bio des Pyrénées-Orientales). In the packing house, the outer skin of the onions is removed and bunches are formed, frequently mechanically (Civam Bio des Pyrénées-Orientales). Leaves are trimmed to approximately 30 cm length, bunches are washed to remove earth attached on the roots and packed in boxes (Civam Bio des Pyrénées-Orientales). Washing water can be cooled to rapidly remove ambient heat from the onions (Oregon State University, 2002a). Bunching onions in the field is also carried out (Oregon State University, 2002a).

2.3.7. Cooling/post-harvest storage

Mature onions must be dried after harvest and before storage to complete drying in the field. Ideally, bulbs should be dried by forced air at 25-30 °C, 65-80 % RH and for 4-6 days once the batch of bulbs has reached the target temperature (Chambre d'Agriculture Rhônes-Alpes, 2011) or by forced air at 35-57 °C, 50-65 % RH during 1-2 days (UGA extension, 2014). Drying is completed by intermittent ventilation for 2-3 weeks at 18-20 °C. The purpose of drying, also called "curing", is not to dehydrate the whole bulb but rather to permit healing of any wounds caused by harvest, to allow complete formation of the layer of dry scales that protect the fleshy scales forming the bulb and to rapidly dry the neck and the remaining roots before soft rot agents can reach the bulb (Chambre d'Agriculture Rhônes-Alpes, 2011; UGA extension, 2014). For long storage onions ('long day' onions harvested at the end of the summer), cured bulbs can be stored for up to 6 months in cool (4-8 °C), dry (70-75 % RH) and well ventilated conditions which avoid any risk of condensation on the bulbs (Chambre

d'Agriculture Rhônes-Alpes, 2011), or for about 9 months in cold rooms (-1 to +1 °C) at 70-75 % RH (Chambre d'Agriculture Rhônes-Alpes, 2011). Controlled atmosphere storage under 3 % oxygen is also used (UGA extension, 2014). For "short day" onions, which cannot be stored for a long time, cold rooms (1 °C) can permit storage for one month (UGA extension, 2014). Cold storage breaks dormancy and induces sprouting of the onion bulbs. To avoid this, chemicals can be applied on the crop before harvest (see for instance current usage registry in France - Ministère de l'agriculture et de l'agroalimentaire (online)).

Green onions are perishable; the leaves must remain green, turgid and are particularly susceptible to moisture loss. Green onions can be stored for 3 to 4 weeks at close to 0 °C and 95 to 100 % RH. At 10 °C, the storage life of green onions is only about 1 week (Oregon State University, 2002a).

In conclusion, harvest and storage differ totally in their objectives for mature onions and for green onions:

- For mature onions, a dry atmosphere is maintained to accelerate healing (curing) of the bulb tissues and to avoid any ingress of post-harvest plant disease agents. The impact of this curing step on foodborne pathogens is not known, but the dry environment would presumably not be favourable to multiplication of *Salmonella*.

- For green onions, harvest and storage conditions are more similar to those of leafy greens, with the need to maintain high moisture content. Concerning the fate of foodborne pathogens, green onions are presumably more similar to leafy greens than to mature onions.

2.4. Description of production systems: garlic

2.4.1. Seed and seedling production

Garlic plants do not form true seeds and are always grown from the bulbs ("cloves"), directly planted in the soil, sometimes in soil covered by plastic lining (Chambre d'Agriculture de la Haute-Garonne, 2004; OMAFRA, 2009). Garlic cloves are planted in autumn from September to November, depending on cultivars, and harvested from May to September (Appendix A, Freshfel information).

2.4.2. Open field production

Garlic is normally cultivated in open fields. Soil requirement and soil preparation is similar to that described for open field onions, with the need of a light soil to permit normal bulb growth, that retain sufficient humidity and good drainage to avoid stagnation of water. Practices to reduce the risk of weeds are also similar for garlic as described for onions.

2.4.3. Water sources and irrigation systems

As for onions, garlic is very sensitive to water stress, particularly during foliage development and bulb growth, but excess water during bulb maturation cause bulb damage. Irrigation is necessary if rain is not sufficient during these periods, but must be stopped during the last weeks before harvest (Chambre d'Agriculture de la Haute-Garonne, 2004). Conversely, in more rainy climates, garlic can be planted on raised beds to increase water drainage (Argouarch'H, 2005). Drip and sprinkle irrigation can be used, although the major irrigation system is sprinkle irrigation.

2.4.4. Different types of fertilisation, organic/manure/compost

As in the case for onions, excess nitrogen for garlic is detrimental to bulb formation. Concerning organic fertilizers, well-matured compost before plantation is recommended, fresh manure being unfavourable to garlic crops (Chambre d'Agriculture de la Haute-Garonne, 2004; Argouarch'H, 2005).

2.4.5. Harvesting

Garlic bulbs intended to be stored are harvested at a stage which is a compromise between yield and bulb quality. Harvesting too late produces damaged bulbs while harvesting too early produces bulbs too rich in water that will shrink during storage (OMAFRA, 2009). A small proportion (around 5 % of the French garlic production) are consumed "fresh" and can be harvested slightly earlier, for instance at the end of May-early June instead of mid-June or July for stored garlic (Larousse Agricole, 2002). However, unlike green onions, "fresh" garlic has a fully formed bulb and leaves are not usually consumed.

Garlic bulbs can be harvested manually or mechanically. In Italy, around 70 % of the production is harvested manually but this proportion may vary in other regions. In both cases, bulbs are lifted by a spade and pulled out. Leaves can be cut at harvest or used to braid several bulbs together. Once harvested, garlic is peeled to remove only the most external layers. Peeling can be done manually or mechanically. In most cases, peeling is done manually for optimal quality. However, between 5 and 10 % of the garlic is peeled mechanically. Water is never used in this process.

2.4.6. Cooling/post-harvest storage

After harvest, garlic bulbs must be 'cured' as described for onion bulbs and with the same purpose. This can be done by natural ventilation or ideally by forced air at 30 °C. Curing is considered completed when bulbs have lost 20-25 % of their weight (Chambre d'Agriculture de la Haute-Garonne, 2004). Once cured, garlic bulbs can be stored at ambient temperature in dry environments (50-60 % HR) for 4 months (autumn cultivars) or 8 months (spring cultivars). Commercial garlic is usually stored under controlled temperature. At cold temperature, usually as near as possible to 0 °C and 50-60 % RH, storage can be increased by up to 6 months for autumn cultivars and by up to 12 months for some spring cultivars stored at -2.5 °C (OMAFRA, 2009) (Appendix A, Freshfel information). Fresh garlic is sold directly after harvest without curing.

2.5. Description of production systems: celery

2.5.1. Seed and seedling production

Celery seeds are very small and germination is difficult. Celery crops are usually obtained from small plants produced from seeds at 20-22 °C over 7-8 weeks in nurseries. Planting of seedlings in soil balls is done in May-June with a harvest in mid-September-October (Argouarch'H, 2005; Chambre d'Agriculture Bouches-du-Rhône, 2013; Civam Bio Gironde). For some cultivars, coated seeds permit direct sowing (Civam Bio des Pyrénées-Orientales, 2008b). Celery is very sensitive to competition from weeds. The same mechanical and thermal techniques, as described for onions, can be used for celery as well.

2.5.2. Open field production

Celery grows best in deep, well-drained soils rich in organic matter. To limit weed growth, planting can be done on soil covered with micro perforated plastic lining to permit homogeneous water distribution in the soil whenever sprinkler irrigation is used (Civam Bio des Pyrénées-Orientales, 2008b).

For blanching, petioles are progressively covered with soil as they grow, taking care not to cover the central bud of the plant. Approximately three weeks before harvest, to complete blanching, the whole plant is covered with soil or a tarpaulin to exclude the light (Argouarch'H, 2005). Alternatively blanching can be completed after harvest (see Section 2.5.7).

2.5.3. Greenhouse production

Protected culture is done with a different production calendar. Small plants are produced from seeds in a nursery over 7-8 weeks. In unheated protected culture (in greenhouses or plastic tunnels) in a Mediterranean climate for instance, for a winter production, planting of small plants in soil balls is

done in mid-August, with a harvest in November-December. For a spring production, planting occurs in March-April for a harvest in May-June (Chambre d'Agriculture Bouches-du-Rhône, 2013). Heated greenhouses permit planting in autumn and harvest in winter (Civam Bio Gironde).

2.5.4. Water sources and irrigation systems

Irrigation is almost always necessary as celery requires an abundant and regular supply of water (Argouarch'H, 2005). In particular, water stress may cause flower formation, which hardens the petioles (Civam Bio Gironde) and results in physiological disorders such as spongy petiole base (University California, 2008). Irrigation techniques used should permit the rapid saturation of soil when needed (University California, 2008). Keeping foliage wet increases the risk of fungal diseases (Civam Bio des Pyrénées-Orientales, 2008b), and drip irrigation can reduce this risk (Oregon State University, 2002b). However, no information was found on the proportions of irrigation techniques and water sources used in EU.

2.5.5. Different types of fertilization, organic/manure/compost

Celery requires significant fertilizer input. A high soil organic matter content being favourable to celery, applying manure is recommended, at e.g. 30 t/ha (Argouarch'H, 2005). However, it should be very well composted to avoid unbalanced nutrition of the celery plant (Argouarch'H, 2005). Other organic fertilizer use includes various commercial compost or green manure (Argouarch'H, 2005). Organic fertilizers should be applied in autumn (Argouarch'H, 2005), which represent, for an open field production, a delay of nearly one year between manure application and harvest.

2.5.6. Harvesting

For harvest, the whole celery plant is either manually or mechanically lifted from the soil with a blade. Roots may be cut in the field or left on the celery plant depending on the post-harvest techniques (Argouarch'H, 2005).

2.5.7. Cooling, post-harvest storage

Celery plants with their roots can be stored in a soil bed in a cool and dark place for 1-2 months, which will also complete blanching of the petioles (Argouarch'H, 2005). Celery plants without their roots can be placed in boxes, after trimming damaged leaves, and stored in cold rooms at 2-3 °C for 1-2 months (Argouarch'H, 2005). Rapid cooling before storage is recommended (Oregon State University, 2002b), however no information was found on pre-cooling practices in EU for celery. During cold storage, celery plants are very sensitive to wilting. High humidity should be maintained, either by protecting boxes with perforated polyethylene films or by maintaining high relative humidity in the cold room (Oregon State University, 2002b).

2.6. Description of EU bulb and stem vegetables and carrots sector

This Section is based on information provided by Freshfel in July 2013 and August 2014 (Appendix A and B which present data on volumes of production and trade for the major bulb and stem vegetables considered in this opinion). Bulb and stem vegetables and carrots on the EU market are predominantly produced in the EU and the share of imports from third countries is limited. The main EU producing countries for bulb vegetables are France, Germany and Italy, while third countries supply ca. 5 % of onions (New Zealand, Egypt, Australia, Chile) and ca. 22 % of garlic (China, Argentina). The main EU producing countries for stem vegetables are Belgium, France and Germany, while third countries supply less than 1 % with the exception of asparagus (12 %, mainly Peru). The main EU producing countries for carrots are Poland, the United Kingdom and Germany, while third countries (Israel, Turkey) supply only 1.7 %.

The most important bulb and stem vegetables and carrots produced are as follows: onions (ca. 6 million metric tons), carrots (ca. 5.5 million metric tons), leeks (ca. 850 000 metric tons), celeriac (ca. 350 000 metric tons), shallots (295 000 metric tons) garlic (ca. 280 000 metric tons), asparagus

(ca. 170 000 metric tons), kohlrabi (ca. 110 000 metric tons) and green asparagus (ca. 90 000 metric tons, mainly Spain and Italy). No detailed figures are available for the other products. As the share of imports from third countries is limited (except for asparagus and garlic), this overview generally corresponds with the importance of the product categories on retail sale. Generally, the main volumes of onions, celeriac and kohlrabi will go to the processing industry, as well as substantial volumes of asparagus and carrots.

There are no detailed statistics available on the share of production of bulb and stem vegetables and carrots sold directly or undergoing processing. Based on more detailed information per cultivar, about one third of the carrot acreage is destined for the processing industry. With regard to onions, about 10 % of the supply in the Netherlands is destined for the processing industry.

3. Risk factors for microbiological contamination during agricultural production

Production practices, growth conditions and contact during growth of the outside vegetable surface with the environment, particularly soil, in combination with intrinsic, extrinsic, harvesting and minimal processing factors will affect the microbial status of bulb and stem vegetables as well as carrots at the time of consumption in a similar way to that outlined for leafy greens and melons (EFSA BIOHAZ Panel, 2014c, e) albeit with different water requirement. Water requirements for the total melon growing period for a 100-day crop range from 400 to 600 mm, while the water requirements for lettuce vary from 200 to 400 mm, depending on the climate. In comparison, the water requirements for the total celery growing period for a 100-day crop is around 400-500 mm (Oregon State University, 2002b); water requirement for green onions varies from 300 – 400 mm, depending on the climate, for a growing cycle of 60-70 days (Oregon State University, 2002a); for mature onions and garlic water requirements vary during the production period, with a peak demand during bulb growth of around 50 mm per week, 12-25 mm per week in other periods, and no irrigation a few weeks before harvest (OMAFRA, 2009; UGA extension, 2014). In addition to the total amount of water used for irrigation, the need for water shortly before, at harvest, and during post-harvest, is presumably more important for the presence and survival of micro-organisms. Green onions and celery need water up to harvest and high humidity post-harvest, in contrast to mature onion and garlic that need dry conditions at these stages. It has been established that water requirements for carrot production are around 20-25 mm per week during the growing season, whereas under warm, dry conditions this may increase to 50 mm (CALU, 2007).

The variability in the production systems and associated environments for production of bulb and stem vegetables, as well as carrots can lead to a wide range of unintentional or intentional inputs that are potential sources of food safety hazards. The sources of contamination will vary considerably from one type of crop production to another as well as between one particular setting/context to another, even for the same crop. The following Sections are intended to identify and characterize potential risk factors for contamination of bulb and stem vegetables as well as carrots in addition to those previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c) but may not be supported by epidemiological or experimental evidence, unless specified in the relevant following Sections.

There is limited or no information available on the risk factors for *Salmonella, Yersinia, Shigella* or Norovirus in these products during primary production; however, when consumed as ready-to-eat or minimally processed products, these vegetables are normally not subjected to physical interventions that will eliminate the occurrence of these pathogens.

3.1. Environmental factors

As with leafy green vegetables (EFSA BIOHAZ Panel, 2014c), environmental factors refer to the specific conditions of the primary production area, climate and type of crop. These factors may have an impact on the safety of bulb and stem vegetables as well as carrots, on microbial contamination routes, persistence of pathogens in fields, the use of fertilizers, sources, quality and frequency of irrigation water and other water uses, and pathogen prevalence and concentration. Onions, garlic and carrots grow in the soil and stem vegetables such as celery have prolonged direct contact with soil

during growth and/or harvesting, particularly when celery is blanched. In addition, bird faeces and airborne contaminants (birds nesting around the growth and packing area, nearby livestock or poultry production, or manure storage or treatment facilities, etc.), and proximity to other wildlife may also pose a risk of contamination. Whether these vegetables are produced in open fields, in protected cultivation, or in soil, all impact the environmental risk factors. Each farm environment (including open field or greenhouse production) should be evaluated independently, as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near bulb and stem vegetable and carrot growing areas.

3.1.1. Factors linked to the adherence, survival and internalisation of pathogens with bulb and stem vegetables and carrots

Bulb and stem vegetables as well as carrots have smooth surfaces. For some of these vegetables, e.g. carrots, onion, garlic, the edible portions have extensive and direct contact with soil but have outer layers which are generally removed before consumption, and for other bulb and stem vegetables, e.g. spring onions, leeks, celery, the edible portions grow above or near the surface of the ground but are liable to soil contamination especially during heavy rain and during irrigation.

Difficulties in interpreting data on the interactions and internalisation of pathogens into leafy greens were previously discussed (EFSA BIOHAZ Panel, 2014c), and despite the very limited data available, this is equally applicable to bulb and stem vegetables as well as to carrots. A cocktail of 10^4 cfu of *Salmonella enterica* (Basildon, Casbana, Enteritidis, Havana, Mbandaka Newport, Poona and Schwarzengrund) added to soil used to sow seeds and grow seedlings showed a high (> 94 %) recovery from the phylosphere of radishes and turnips which was significantly higher than that for carrots (ca. 74 %) and lettuce (ca. 60 %) or tomato (ca. 46 %) seedlings (Barak et al., 2008). Furthermore, *Salmonella enterica* serovars Newport, St. Paul, Typhimurium and Montevideo were shown to survive in six week old leek shoots, as well as root and soil samples over a 22 day period, but were shown to persist in significantly higher numbers in the presence of the mycorrhizal fungus *Glomus intraradices* (Gurtler et al., 2013). Although radishes and turnips were previously classified as a root vegetable and not as a bulb and stem vegetable (EFSA Panel on Biological Hazards (BIOHAZ), 2013a), these plant species are included here to provide more information on interactions between these pathogens and plants.

In a gnotobiotic system, carrot and radish seeds soaked in solutions containing 10^2 cfu/ml of *S.* Typhimurium (resulting in 3-4 log cfu/g of seeds) and after plant growth for 49 days in hydroponic solution showed multiplication up to 6 log cfu/g of plant tissue (Jablasone et al., 2005). *Salmonella* were detected on the surfaces of these plants with internalised populations of the bacterium within the radish seedlings (Jablasone et al., 2005). In 4 week old spring onion plants inoculated with 1, 3 and 5 log cfu/plant of *S.* Typhimurium, internalised bacteria were observed after two days in both the lower as well as the upper parts of the plant (Ge et al., 2013). The level of internalized *Salmonella* was significantly greater in the lower part of the plant, especially when exposed to higher inoculum 5 log cfu/plant (Ge et al., 2013). There is no similar data for other plants and *Salmonella*, or other bacterial foodborne pathogens including *Yersinia, Shigella* and Norovirus. Internalization has been observed after artificial inoculation of high levels of *Salmonella*, making it difficult to assess its importance under natural conditions.

The possibility that lower eukaryotic organisms (particularly nematode worms) may act as a temporary reservoir for *Salmonella* in the soil and increase the dispersal and survival of pathogens in agricultural environments was discussed in relation to the propagation on leafy greens (EFSA BIOHAZ Panel, 2014c). The same effects are applicable to bulb and stem vegetables as well as carrot production. Kenney et al. (2006) demonstrated the potential of the nematode *Caenorhabditis elegans* to serve as a vector for the transport of *S.* Newport to the surface of carrots present in soil with bovine manure. It is not known, however, if similar effects occur for other bulb and stem vegetables as well as for other pathogens including *Yersinia, Shigella* or Norovirus.

The capacity for Human Norovirus to persist in an infectious state on the surface of bulb and stem vegetables as well as carrots is not known, due to the inability to culture the virus. No information is available on the potential for Norovirus to internalise within these vegetables. However, internalisation of surrogate viruses has been observed in experimental studies. Murine Norovirus can be internalised in green onion tissues after the plants were grown in hydroponic systems in which a nutrient medium was inoculated with several logs infectious units of the virus (Hirneisen and Kniel, 2013a): the virus remained infectious for at least 5 days after internalisation, with no decline in infectivity. No internalisation was observed in green onion plants grown up to 20 days in soil when the virus was inoculated into soil substrate, possibly due to adsorption by particulate matter hindering root uptake. These results do nonetheless demonstrate the possibility that viruses may become located in bulb tissue e.g. following exposure through irrigation water. However, the virus levels used in experimental studies may be higher than those which are likely to be encountered during crop production; furthermore, information on Norovirus internalisation gained through use of surrogates should be interpreted with caution, as properties of different viruses may affect uptake into, or clearance from, plants.

3.1.2. Conditions in the field and adjacent land

The conditions in the growing field as well as in adjacent land were identified as playing a vital role in the microbial safety of leafy greens (EFSA BIOHAZ Panel, 2014c) and these risk factors are likely to be equally applicable to bulb and stem vegetables as well as carrots. Risk factors for contamination with pathogens include contact of these vegetables with airborne contaminants as well as those from the soil, animal droppings, soil amendments (including natural fertilizers) or direct contact with irrigation water. Risks are consequently associated with runoff and flooding particularly where adjacent land use is associated with contamination from human or animal excreta. In greenhouse-grown crops, risks are reduced when contact with the soil is minimized.

3.1.3. Climatic conditions

The effects of climatic conditions on the contamination sources and pathways for pathogens to contaminate leafy greens during the pre-harvest phase were previously outlined (EFSA BIOHAZ Panel, 2014c) and risk factors previously identified are also applicable to bulb and stem vegetables as well as carrots. Heavy rains may increase the exposure to pathogens through contaminated soil, as well as causing contamination through flooding and where floodwaters come into direct contact with the vegetables.

3.1.4. Contact with animal reservoirs

Domestic animals (cattle, sheep, chickens, pigs, dogs, cats, and horses) as well as wild animals (e.g. frogs, lizards, snakes, rodents, foxes, deer, badgers or wild boar) and birds can contaminate leafy green crops with their faeces if they are present in growing areas (EFSA BIOHAZ Panel, 2014c) and risk factors previously identified are likely applicable to bulb and stem vegetables as well as carrots.

Bulb and stem vegetables as well as carrots can have high sugar content and are attractive to various pests including free-living nematodes that may cross-contaminate the vegetables (see Section 3.1.1). While domestic animals may be separated from growing operations for these vegetables, it can be more difficult to control access by wild animals and birds. Wild and domestic animal species (as well as humans) represent risk factors for contamination of these vegetables with pathogens when they are present in the production environment, and present a risk both from direct contamination of the crop and soil as well as from contamination of surface water sources and other (particularly water) inputs. Bird droppings and airborne contaminants (birds nesting around the packing area, nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contaminating these vegetables with pathogens. In the 2004 outbreak of *Y. pseudotuberculosis* outbreak in Finland, the implicated strain was recovered from a pooled sample of the intestinal contents of the common shrew (*Sorex araneus*) collected from one of two farms where the carrots were grown (Kangas et al., 2008).

3.2. Organic amendments (manure, slurries, composts, wastewater treatment, sludge and sewage)

The use of untreated manure and liquid manure are risk factors for contamination of bulb and stem vegetables as well as carrots. The persistence of foodborne pathogens has been highlighted previously for leafy greens (EFSA BIOHAZ Panel, 2014c) and depending on length of the production cycle, these vegetables can be contaminated by pathogens from organic amendments used during cultivation. Islam et al. (2004) reported that *S.* Typhimurium survived in soil containing compost for up to 231 days and was detected for 84 and 203 days on radishes and carrots sown into this soil. Similarly, Natvig et al. (2002) also demonstrated the survival of *S.* Typhimurium in contaminated manure for at least 15 weeks in some soils and on growing carrot and radish plants. Greater *Salmonella* survival was detected if manure application was carried out in the summer (daily average temperature > 20 °C) than in the spring (daily average temperature < 10 °C; (Natvig et al., 2002). There is no information on the survival and persistence of *Yersinia, Shigella* or Norovirus in similar systems. Section 2 of this opinion gives some indications on the times organic fertilizers are applied on some bulb and stem vegetables as well as carrots. As discussed for leafy greens (EFSA BIOHAZ Panel, 2014c), composting manure may reduce non-spore forming bacterial foodborne pathogens by several logs. Section 2 of this opinion shows that, to fertilize bulb and stem vegetables, composted manure is also preferred to raw manure for agricultural reasons.

3.3. Water use during production (irrigation, pesticides and fertilizers, washing)

Clean water should only be used for bulb and stem vegetable production as well as for carrot production and, as with leafy greens (EFSA BIOHAZ Panel, 2014c): water from contaminated sources represents a major risk factor for contamination with pathogens. Risks can be minimised by growers identifying the sources of water used on the farm (e.g. municipal water, reclaimed wastewater, discharge water from aquaculture, well water, open canal, reservoir, rivers, lakes, farm ponds, etc.). The risks posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm for the presence of pathogens which should include documented checks detailing the potential for microbial contamination from all possible human and/or animal faecal sources of contamination (e.g. from animals, human habitation, leaks from in-field sanitary facilities, sewage treatment, manure and composting operations) and the water's suitability for its intended use. In the case of identified contamination sources of the water used on the farm, corrective actions should be taken to minimize the risk. The effectiveness of corrective actions should be verified.

There is evidence that associates irrigation water quality as an important risk for pre-harvest contamination of radishes and carrots by *S.* Typhimurium for up to 84 days (Islam et al., 2004). The risk of sewage or wastewater contaminating vegetables with human foodborne pathogens, including *Salmonella*, has been reviewed (Bryan, 1977) although there is no specific information on the survival and persistence of *Yersinia, Shigella* or Norovirus associated with the growth of bulb and stem vegetables as well as carrots. However, it is clear that a wide range of pathogens can occur and persist in water, as well as surviving in agrichemical solutions, including pesticides. The application of aqueous fertilizers and pesticides prior to and during harvest may represent a risk if water is contaminated with pathogens when used in water-based chemical treatments (PMA, 2013).

Water can also be used during post-harvest handling and washing which, if done correctly, may reduce microbial loads on the outside surface of these vegetables; however, this may also act as a source of cross-contamination. Although there is no specific information available on the effects of post-harvest washing for *Yersinia, Shigella* or Norovirus, some reduction, but not elimination, of *S.* Typhimurium was detected in washed radish, although the bacterium was also detected in the wash water that represents a risk of cross-contamination for subsequently washed vegetables (Natvig et al., 2002). Water used for post-harvest cooling may also be a significant source of microbial cross-contamination if this is of poor quality or where there is insufficient disinfectant present. Wet surfaces from cooling operations or from dew may permit survival and, in some instances, multiplication of human pathogens on vegetable surfaces.

3.4. Equipment

Risks associated with contamination from equipment and handling were previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c), which can occur at any point in the farm-to-plate continuum, and these risk are equally applicable to bulb and stem vegetable production as well as to carrots. Harvest equipment (knives, pruners, machetes and other cutting equipment), together with transport containers and any farm machinery (gondolas, trailers or wagons), which comes into contact with these types of vegetables, represents a risk factor for contamination. Some bulb and stem vegetables (e.g. green onions, celery, carrots) are typically cooled by forced-air, chilled water, or by use of a chilled room. Forced-air and hydro-cooling operations may also spread product contamination if forced air cooling equipment and cooling water is not cleaned and sanitized regularly (PMA and UFFVA, 2005). In a *Y. pseudotuberculosis* outbreak linked to grated carrots in Finland, the investigators noted that storage facilities were open to access by rodents (Jalava et al., 2006).

Mature onions bulbs and garlic are cured by dry warm air. The risk of spreading foodborne pathogens is not known.

3.5. Worker health and hygiene, worker training

The risk represented by people working with bulb and stem vegetables as well as carrots by the transfer of micro-organisms of public health concern through direct contact is similar to that previously considered for leafy greens eaten raw as salads (EFSA BIOHAZ Panel, 2014c). Based on information provided by Freshfel in June 2015, it should be noted that, in contrast to many other foods of non-animal origin such as leafy greens, berries, tomatoes or melons, carrots and bulb and stem vegetables are not usually harvested manually although in some regions these vegetables can be handled extensively during harvest and during further sorting and packing (Appendix A, Freshfel information). Thus, as for all other foods of non-animal origin, personal hygiene is critical as manual harvesting and subsequent handling could lead to contamination. The health and hygiene of harvesters and other food handlers are critical factors in pathogen contamination, and failure to adhere to scrupulous hand hygiene is one of the major risk factors. Therefore, improper, careless and poor handling both in the field and at packing stations (together with inadequate sanitary and hand washing facilities) can be detrimental, not only for vegetable quality but also for vegetable safety. However, types of bulb and stem vegetables do not require the same amount of handling, with, for example, green onions receiving more handling at harvest and post-harvest than mature onions and garlic. In addition, an inedible skin protects mature onions and garlic, which does not occur for other vegetables such as green onions and celery.

3.6. Conclusions

The risk factors at primary production for the contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus are poorly documented in the literature, with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce:

- environmental factors, in particular proximity to animal-rearing operations and climatic conditions that increase the transfer to pathogens from their reservoirs to the bulb and stem vegetables and carrot growing areas;
- animal reservoirs (domestic or wild life) gaining access to growing areas for bulb and stem vegetables or carrots;
- contamination or cross-contamination by equipment at harvest or post-harvest, and by manipulation by workers if this takes place at primary production;
- use of untreated or insufficiently treated organic amendments;

- use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as pesticides.

Processes at primary production, which wet the external portions of the crop close to harvest, represent the highest risk and these include spraying prior to harvest, direct application of fungicides and other agricultural chemicals and overhead irrigation.

4. Description of minimal processing methods for bulb and stem vegetables and carrots

Bulb and stem vegetables as well as carrots may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, cutting, packaging and storage. Other types of minimal processing (e.g. commercial unpasteurized juicing etc.) rarely occur outside retail and catering, and are not further considered in this Section. Unpasteurized juicing may take place at retail or catering (especially for carrots) and is considered in Section 6. Freezing may take place, but this will typically involve a heat blanching process and is outside the scope of this opinion, although frozen sliced onion may not be blanched (Baert et al., 2008). Bulb and stem vegetables as well as carrots may be subject to cooking, drying, bottling, canning and other processes, but these are also outside the scope of this opinion.

As with leafy greens (EFSA BIOHAZ Panel, 2014c), if a washing process is applied during minimal processing, the quality of the water used for washing bulb and stem vegetables as well as carrots is a key consideration. Where these vegetables are washed, there will be some effect by reducing the microbiota (including pathogens) but it may also result in cross-contamination if the microbial quality of the process water is not controlled using a disinfectant treatment. Thus, the main goal of using disinfection agents will be to prevent cross-contamination between different batches of vegetables. As for leafy greens (EFSA BIOHAZ Panel, 2014c), chlorine-derived compounds are the most frequently used disinfectants during washing in commercial facilities to maintain the quality of the water, depending upon national policies for their use and approval for the use of disinfectants. The required free chlorine doses applied to the washing tank will vary depending on the concentration of organic matter in the process water, although a residual concentration of at least 10-20 ppm of free chlorine is recommended. In addition, other treatments (e.g. chlorine dioxide, peroxyacetic acid, hydrogen peroxide, electrolyzed water) have been used on a more experimental basis and are further discussed in Sections 9.3 and 9.4. Whenever disinfectants are used, the last stage before packaging should be the rinsing step, which requires very low doses of disinfection agent to maintain the hygienic quality of the water.

Based on their behaviour in other vegetable food matrices, survival of *Salmonella, Yersinia* and *Shigella* is likely to occur on both ambient-stored as well as refrigerated bulb and stem vegetables as well as carrots, although there have been limited studies to support this for the specific food types. Amongst foodborne pathogens considered here, *Yersinia enterocolitica* and *Y. pseudotuberculosis* are the only psychrotrophic micro-organisms and are able to replicate at temperatures below 7 °C. Norovirus may be able to persist in an infectious state on these vegetables stored at ambient and at refrigeration temperatures; however, apart from data obtained during outbreaks, no studies are available to confirm this.

4.1. Onion (washing, peeling and cutting, shredding, packaging)

Green onions are often marketed after a minimal process that consists of washing, draining, cutting both the roots remaining after harvest and part or all of the stem plate, leaving the very short and compacted stem that carries the leaves forming the bulb and on which are attached the roots (Hong et al., 2000). Although minimal, this process induces several physiological changes in the plant tissue (Hong et al., 2000; 2004) and represents a potential source of contamination. Minimally processed green onions can be packaged and sealed to prevent moisture loss and stored refrigerated.

Mature bulbs of onion can be peeled and sold as whole peeled onion, or peeled and cut into slices or diced (Blanchard et al., 1996; Perez-Gregorio et al., 2011). Sliced or diced onion can be sold as such

or mixed with other pre-cut vegetables. Peeling onion for removal of the skin can be done by cutting combined with mechanical procedures, by compressed air, or by abrasion in a water bath. Various washing procedures, with and without disinfectant, for onion slices or dices have been used, followed by draining and packaging under various films or atmospheric conditions (Blanchard et al., 1996; Perez-Gregorio et al., 2011; Berno et al., 2014), but no information was found on the practices actually used in the EU.

Onion tissues can release antimicrobial compounds upon cutting or crushing (Lund, 1992). However, onions are also rich in sugars and with pH 5.0 to 5.8, and diced onion supported a 3 log growth of aerobic bacteria at 4 °C in one week (Blanchard et al., 1996).

At 4 °C, in an atmosphere containing approximately 10 % CO_2, a shelf life of 2 weeks was reported for diced onions (Blanchard et al., 1996).

4.2. Garlic (washing, peeling, packaging)

Garlic can be minimally processed as peeled garlic and is available at retail sale in EU, including in Spain and Italy. Cloves must be separated from garlic bulbs prior to peeling. Then, cloves are mechanically peeled and the clove left whole for optimum freshness. Among peeling machines available for garlic, some use abrasion in association with water but most use compressed air to eliminate the outer layers. Park et al. (1998) compared dry and wet peeling of garlic and found that wet peeling produced cloves with a 10 to 100-fold higher counts of total aerobic bacteria. If dry peeling is applied, peeled garlic is washed in refrigerated water and dried. If a washing tank is used, disinfectant agents can be used during washing to maintain the quality of the process wash water. Pre-peeled garlic gloves are stored under refrigerated temperatures to maintain quality. The following considerations are important to maintain the quality of fresh peeled garlic: 1) reduce mechanical injury during the peeling process; 2) storage as near as possible to 0 °C; 3) use of modified atmospheres with 0.5 % O_2 and 10 % CO_2 to retard discoloration and decay as well as sprout development in fresh peeled garlic stored at 5-10 °C (Cantwell et al., 2003).

4.3. Celery (washing, peeling, cutting, packaging)

Celery can be minimally processed to various degrees, cutting off petioles to keep the “heart”, using petioles to produce celery sticks, or celery slices (University California, 2008). No information was found on the relative frequency of these different minimal processes applied to these products in the EU and no description of the processing lines was available. Celery sticks and celery dices are presumably processed as described for leafy greens, with pre-washing, cutting or slicing, washing or disinfection, rinsing, draining and packaging (Gomez and Artes, 2005). A shelf life of packaged celery sticks of 10 days at 4 °C was reported (Gomez and Artes, 2005).

4.4. Carrot (washing, peeling, cutting, packaging)

Carrots can be minimally processed to various degrees. Minimally processing of carrots is usually done in a different processing plant, separately from the post-harvest handling plant. The product is first peeled and then washed after removal of the top and the bottom of the carrot. Carrots are peeled with abrasive peeling or knives. Washing is usually carried out in a washing tank and the water is refreshed on a regular basis. In some cases, the minimal processing is carried out by the carrot producers, which sell to fresh-cut companies. The fresh-cut companies get ready-to-eat carrots, and pack them as final product. Carrots are then sold as an individual product or mixed with other types of ready-to-eat vegetables (Appendix A, Freshfel information).

Ready-to-eat carrots are usually stored at a maximum temperature of 6 ºC and the shelf-life is usually six days after minimal processing. Commercial ready-to-eat carrots are not commonly packed under modified atmosphere packaging (MAP) (Appendix A, Freshfel information).

White blush, due to dehydration of cut or abrasion-peeled surfaces, has been a problem on fresh-cut carrots. Sharp cutting blades and residual free-moisture on the surface of the processed carrots will significantly delay the development of the disorder (Suslow et al., 2002).

5. Risk factors for microbiological contamination during minimal processing treatments, including the main minimal processing practices

The surface of intact bulb and stem vegetables as well as carrots can be dry or waxy and the pH, water, protein and sugar content for carrots and onions as compared with lettuce, melon and tomatoes is shown in Table 2. However, after minimal processing of bulb and stem vegetables as well as carrots, the surface properties change and there is an increased risk of bacterial contamination, persistence or growth of both spoilage organisms and potential pathogens, by breaking the natural exterior barrier of the produce. In general, survival of foodborne pathogens on produce is significantly enhanced once the protective epidermal barrier has been broken. However, there are opposing effects both from inhibition by naturally occurring substances within the plant tissue, and interference from the natural microbiota, including the reduction in pH by the metabolism of lactobacilli.

A mixture of five *Salmonella enterica* serovars (Michigan, Montevideo, Enteritidis, Agona and Gaminara) inoculated onto cut celery in closed containers for up to 7 days declined by approximately one log at 4 °C, did not change at 12 °C, but increased by approximately 2 log cfu/g at 22 °C (Vandamm et al., 2013). In grated carrot, a mixture of *Salmonella enterica* serovars (Typhimurium, Typhi, Infantis and Concord) incubated over 6 days did not show growth at 7 °C or for 2 days at 7 °C followed by 4 days at 15 °C. However, *Salmonella* did increase by approximately 1 $\log_{10}$ where stored at 15 °C despite an approximate 3 $\log_{10}$ increase in lactic acid bacteria at the higher temperature (Sant'Ana et al., 2012). Growth of *S.* Typhi was detected on cut surfaces of carrot stored at 32 °C for 6 hours (Viswanathan and Kaur, 2001). There is therefore limited data for the behaviour of *Salmonella* in the specific vegetable food matrices, and no information available for *Yersinia, Shigella* or Norovirus.

Table 2: pH, water, protein and sugar content of selected fruit and vegetables[(a)]

Vegetable	pH	Water (g/100 g)	Protein (g/100 g fresh weight)	Sugar (g/100 g fresh weight)
Carrot	4.9-6.3	88.3	0.93	4.5
Onion	5.0-5.8	88.5	0.9	4.3
Lettuce	6.0-6.4	95.6	0.9	1.7
Melon (Cantaloupe)	6.2-6.5	90.2	0.84	7.8
Tomato (ripe)	3.4-4.7	94.5	0.88	2.6

(a): Data from Carlin (2007).

Various *in vitro* antimicrobial activities active against enteric pathogens from plant extracts have been detected, especially in garlic (Kim and Kim, 2007; Irkin and Korukluoglu, 2009; Gull et al., 2012), onion (Bakht et al., 2014) and carrots (Rokbeni et al., 2013). Some antimicrobial compounds are generated upon cutting or mashing the plant tissues, as in onion and garlic (Lund, 1992; Ahsan et al., 1996).

5.1. Environmental factors

Environmental factors refer to the specific conditions of the processing area, which might have an impact on the safety of the bulb and stem vegetables as well as carrots and have been previously considered for leafy green vegetables (CAC, 2003). The environment of the processing plant may represent a risk for cross-contamination between products. The production environment is likely to be refrigerated, which, if the product has not already been refrigerated, should be implemented immediately after harvesting and would prevent the growth of most pathogenic bacteria.

5.2. Water sources (washing and other uses)

Washing, if applied, is an important step in the minimal processing of bulb and stem vegetables as well as carrots. Risk factors previously identified for leafy greens (EFSA BIOHAZ Panel, 2014c) are applicable to bulb and stem vegetables and carrots. For *Salmonella*, *Yersinia* and *Shigella*, this risk of cross-contamination during washing is reduced if disinfectants are properly used within the washing tank. Maatta et al. (2013) detected *Y. enterocolitica* by PCR in washed, peeled and grated carrots as well as process wash water, but were unable to isolate the bacterium from these samples; details on any sanitation agents used in the water were not provided in this report. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

5.3. Equipment

Risks from contamination via process equipment were previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014c), and will be equally applicable to bulb and stem vegetables as well as carrots. Equipment in the minimal processing environment such as knives and other cutting equipment used in post-harvesting, as well as the conveyor belts or utensils used for minimal processing, may act as vehicles for cross-contamination for these vegetables. In an outbreak of *Y. pseudotuberculosis* associated with grated carrots in 2003 in Finland, soil samples that contained carrot residue were obtained from peeling and washing equipment at the production site and were shown to be contaminated with *Y. pseudotuberculosis* strains, which were indistinguishable by PFGE from the outbreak strains (Jalava et al., 2006; Kangas et al., 2008).

5.4. Worker health and hygiene, worker training

Although minimal processing of carrots and onions and other bulb and stem vegetables involves many types of equipment, in some regions or for some of these vegetables (e.g. peeling of garlic) minimal processing may still involve extensive manual handling. As previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014c), lack of compliance of workers with Good Manufacturing Practices (GMPs) and Good Hygiene Practices (GHPs) and food safety management systems (including HACCP) are risk factors for minimal processing of bulb and stem vegetable as well as minimal carrot-processing. Mitigation options include adequate training as well as hand washing and toilet facilities, which are further considered in Section 16.2.7.

5.5. Conclusions

During minimal processing, contamination or cross-contamination via equipment, water or food handlers are likely to be the main risk factors for contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus.

There is limited information on the behaviours of *Salmonella, Yersinia, Shigella* or Norovirus in the specific vegetable food matrices, but these pathogens are likely to survive on the surfaces of these vegetables for days to several weeks at both ambient and at refrigeration temperatures.

6. Description of the distribution, retail and catering including domestic and commercial environments for bulb and stem vegetables and carrots

At retail, bulb and stem vegetables as well as carrots can be sold as whole vegetables displayed in bulk at ambient temperature, which is common practice for carrots, mature onion bulbs, and garlic, but is also frequent for other bulb and stem vegetables. These vegetables can also be presented as packaged products after various degrees of minimal processing and, in such cases, are most often displayed in cold cabinets. This is the case with pre-peeled garlic, which is usually peeled using compressed air, washed, packaged under modified atmospheres and stored as near as 0 ºC as possible to maintain quality. Pre-peeled garlic, also known as garlic cloves, is commonly used as an ingredient to prepare other foods.

In addition to being sold as whole vegetables, bulb and stem vegetables as well as carrots are also sold as loose cut and shredded products in salad mixes at both retail and in catering and in salad bars,

sometimes allowing for self-selection and service by the consumer. Bulb and stem vegetables and carrots may also be subject to further types of minimal processing (e.g. cutting, mashing and repackaging) and, particularly for carrots, are also used for production of unpasteurised juices (often mixed with other fruits or vegetables) usually for immediate consumption or with very short shelf lives.

At catering and in domestic environments, bulb and stem vegetables are served as fresh cut products often mixed with other vegetables or salad products as well as being added as an additional flavouring to more complex foods such as gazpacho or salsa, or as garnishes such as garlic or onions. Fresh garlic is also crushed and the juice added to dishes or mixed with other ingredients to prepare pastes and pestos, used to rub bread. All these examples of preparations involve handling and represent generic opportunities for cross-contamination.

Washing of the product may take place in a similar manner to that outlined in primary minimal processing, but is more likely to be in sinks with running potable water used for general food handling. Hygiene practices for preparation of fresh-cut bulb and stem vegetables during catering in the EU are very diverse and similar to those described for leafy-greens. For instance, in the UK, Sagoo et al. (2003) described handling conditions for salad vegetables which included carrots, celery, and onions. The authors reported that salad vegetables were only displayed at chill temperatures (below 8 °C) in two thirds of the establishments surveyed; specific serving utensils were used by only one third of these establishments, while use of bare hands to handle salad was observed in another third.

Contaminated salsa was associated with a salmonellosis outbreak in the USA (Campbell et al., 2001) and survival and growth of *Salmonella* was affected by the amount of lemon juice or garlic added during preparation (Ma et al., 2010). Although the lemon juice (as well as vinegar and other organic acids) will be effective at reducing and preventing the growth of food poisoning bacteria, including *Salmonella* (Sengun and Karapinar, 2004), there was evidence of an independent inhibitory effect of garlic against *Salmonella* (Ma et al., 2010).

7. Risk factors for microbiological contamination during distribution, retail and catering including domestic and commercial environments

Risk factors during distribution, retail and catering for bulb and stem vegetables as well as carrots are likely to be the same or similar to those for leafy greens (EFSA BIOHAZ Panel, 2014c), although they are not generally supported by published studies. The primary risk factors are contamination from the environment (e.g. hygiene of premises and storage rooms), cross-contamination through direct or indirect contact with contaminated water or equipment or handling by infected persons. The quality of the raw material purchased by the caterer may be an important risk factor, particularly for vegetables such as carrots that can be stored for several months in high humidity cold rooms, conditions that could be favourable to growth of psychrotrophic pathogens such as *Y. enterocolitica*, particularly in damaged carrot tissues (Rimhanen-Finne et al., 2009).

7.1. Water sources (washing)

As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c), water that has been contaminated with bacteria and viruses, and is then used in food preparation, can cause contamination of bulb and stem vegetables as well as carrots. This represents a similar contamination or cross-contamination risk to that which can occur during minimal processing (see Section 5.2). Baert et al. (2008) demonstrated, using Murine Norovirus, that the potential exists for viruses in contaminated water used for washing to be transferred the surfaces of onion bulbs: over 3 log infectious units could be detected on the onion bulbs after washing in water containing 5 log infectious units. It has been shown that viruses (including Norovirus) can be transferred from contaminated liquid to the surfaces of other foods (Gerba and Choi, 2006; Rodriguez-Lazaro et al., 2012). There is no direct experimental evidence for transfer of bacterial foodborne pathogens to bulb and stem vegetables as well as carrots by this route, although it has the potential to occur.

7.2. Equipment, worker health and hygiene, worker training

Due to the wide diversity of foodstuffs potentially prepared and handled in catering establishments, bulb and stem vegetables as well as carrots can become contaminated. Contamination or cross-contamination may occur from food contact surfaces, food handlers or from other foodstuffs including foods of animal origin and, although well documented with other foods (Bolton et al., 2014), there is only limited evidence of this for bulb and stem vegetables as well as carrots.

In a simulation of cross-contamination within minimal processing environments and domestic kitchens, *Salmonella* was readily transferred from the surfaces of freshly cut celery and carrots to a variety of ceramic, glass, plastic, and stainless steel surfaces (Jensen et al., 2013). This highlights the importance of segregation of food contact surfaces, for example between raw meat and ready-to-eat foods of non-animal origin. The investigation of a *Y. enterocolitica* outbreak caused by consumption of grated carrot in Finland found the surface of the storage facilities of the vegetable distributor contaminated by the outbreak strain (Rimhanen-Finne et al., 2009).

Contamination of leafy greens with both *Salmonella* and Norovirus through contact with the hands of infected persons during preparation was previously discussed (EFSA BIOHAZ Panel, 2014c), and similar risks occur with respect to the contamination of bulb and stem vegetables as well as carrots, which will also apply to *Yersinia* and *Shigella*. Poor hand hygiene (e.g. not washing thoroughly) following use of toilet facilities prior to handling of foodstuffs is an important and universal risk factor for contamination of food. Risk factors for bulb and stem vegetables as well as carrots in restaurants will include the potential for cross-contamination between products and utensils as well as from poor food handler and consumer hygiene.

Shigella can spread from infected individuals by fingers and thus touched utensils or food contact surfaces can result in contamination or cross-contamination of food. Binet and Lampel (2013) reviewing historical literature concluded that *S. sonnei* can survive for over 3 h on fingers, and for more than 2 to 28 days at 15 °C and up to 13 days at 37 °C on metal utensils.

There is the possibility for Norovirus contamination from food products to spread via cross-contamination through contact with minimal processing or preparation surfaces as previously discussed (EFSA BIOHAZ Panel, 2014c). For example, this could occur through cutting of a contaminated item followed by using the same utensil to cut uncontaminated items without adequate cleaning between each steps (Wang et al., 2013a; Shieh et al., 2014).

Stals et al. (2013) demonstrated that Norovirus GII.4 could be transferred from gloves to a stainless steel surface and from that to foodstuffs, and vice versa. In addition, Tuladhar et al. (2013) showed that transfer of Human Norovirus from finger pads to foods is possible even after the virus is dried on the surface of the hands.

7.3. Storage temperature

During distribution, retail, catering and in domestic environment, whole mature onion bulbs and whole garlic bulbs are usually stored at ambient temperatures. Whole green onion and celery are normally stored refrigerated and packaged to prevent moisture loss, although they can be displayed at ambient temperature at retail. Minimally processed onions, garlic, green onion and celery are generally stored at refrigeration temperatures.

Shigella and *Salmonella* have a minimum temperature for growth at or above 7 °C. But *Yersinia* is a genus of psychrotrophic organisms with the ability for growth at usual refrigeration temperatures (0-7 °C), the latter being well documented for *Y. enterocolitica* on a wide range of foods (Robins-Browne, 2013). The growth of *Y. pseudotuberculosis* in raw ground beef at temperatures ranging from 0 to 30 °C was also described (Bhaduri and Phillips, 2011). Thus, for example, storage of carrots for an extended period in high humidity cold rooms might enable *Yersinia* to multiply and grow. However, no studies are available quantifying the extent of growth on carrots or other bulb or stem

vegetables stored in cold conditions. It should be noted however that Liao (2007) reported *Y. enterocolitica*, as well as *Salmonella,* to show very little growth (< 1 log unit) on unsanitized baby carrots when incubated for 2 days at 20 °C. But on sanitized carrots (using 200 µg of active chlorine) the growth of *Y. enterocolitica* (as well as *Salmonella*) increased 2 to 3 log units, although the growth of both pathogens was inhibited when co-inoculated with a natural carrot microbiota. Thus it was shown that the presence of a high level of native microbiota (≥ 10^4 cfu/g tissue) on baby carrots greatly limited the growth of these food borne pathogens. The inhibitory effect of carrots on pathogens is thought to be, in part, due to the antimicrobial activity of carrot tissue and, in part, due to the antagonistic action of associated microbiota (Liao, 2007).

7.4. Conclusions

At distribution, retail and catering and in domestic and commercial environments, contamination and cross-contamination, in particular via direct or indirect contact between raw contaminated food and bulb and stem vegetables, is a risk factor for *Salmonella, Yersinia, Shigella* and Norovirus. Cross-contamination risks can also occur in the salad bar environments.

At distribution, retail, catering and in domestic or commercial environments, infected food handlers are also risk factors (particularly for Norovirus and *Shigella*). Contamination can be direct or indirect via poor hand hygiene or food contact surfaces. These contamination and cross-contamination risks include salad bar environments.

These pathogens are likely to survive on the surfaces of these vegetables for days to several weeks at both ambient and at refrigeration temperatures.

8. Pathogen occurrence on bulb and stem vegetables and carrots

8.1. *Salmonella*

8.1.1. Analytical methods for the detection and enumeration of *Salmonella* in bulb and stem vegetables and carrots

As previously outlined (EFSA BIOHAZ Panel, 2014c), methods for detection of *Salmonella* in FoNAO are well developed and analytical reference methods standardised and widely adopted across laboratories testing food, including that for Official Control: EN/ISO standard method 6579[13] which is prescribed in Regulation 2073/2005[14] when analysing pre-cut ready-to-eat fruit and vegetables in the scope of the verification of compliance with the currently established food safety microbiological criterion for *Salmonella*. Alternative methods based on modifications of the ISO method using alternative enrichment media or isolation media (chromogenic media) or using immunoassays and real time PCR are also available for rapid detection of *Salmonella,* and many of these methods have been ISO 16140[15] validated showing performance characteristics equivalent to the EN/ISO standard method 6579 (EFSA BIOHAZ Panel, 2014c).

8.1.2. Data on occurrence and levels of *Salmonella* on bulb and stem vegetables and carrots

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Salmonella* in the EU Member States and there are limited data on the occurrence of *Salmonella* in/on these vegetables in the peer-reviewed world literature (Table 3). There are limited data available from studies on the occurrence of *Salmonella* in/on these vegetables, and some of these studies are small (e.g. comprising < 20 samples) with a variety of methods and sample sizes hence there are difficulties in making meaningful comparisons between individual studies and in establishing the

[13] EN/ISO 6579:2002. Microbiology of food and animal feeding stuffs - Horizontal method for the detection of *Salmonella* spp. International Organization for Standardization, Geneva, Switzerland.
[14] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.
[15] ISO 16140:2003. Microbiology of food and animal feeding stuffs – Protocol for the validation of alternative methods. International Organization for Standardization, Geneva, Switzerland.

representativeness of the data on occurrence of the bacterium to estimate the overall levels of contamination. The majority of the samples were collected outside the EU. It is not possible to include occurrence data on contamination of these vegetables by *Salmonella* within zoonoses monitoring data (according to the Directive 2003/99/EC)[16] since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits.

[16] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 3: Occurrence of *Salmonella* in bulb and stem vegetables and carrots

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[a]	Sample size	Reference
Retail (distribution centres and markets)	Scallions and green onions	Canada	Health Canada Compendium of Analytical Methods MFHPB-20	173	0	0.0	[0, 1.4]	25 g	(Arthur et al., 2007)
Retail supermarkets	Grated carrot	Spain	ISO 6579:2002	18	0	0.0	[0, 12.9]	25 g	(Abadias et al., 2008)
Retail farmer's markets	Carrots	Canada	Health Canada MFLP-29	206	0	0.0	[0, 1.2]	25 g	(Bohaychuk et al., 2009)
Retail farmer's markets	Green onions	Canada	Health Canada MFLP-29	129	0	0.0	[0, 1.9]	25 g	(Bohaychuk et al., 2009)
Retail markets and street vendors	Green onion	Saudi Arabia	Rappaport-Vassilidis enrichment screened by PCR	6	0	0.0	[0, 33]	25 g	(Hassan et al., 2011)
Retail markets and street vendors	Celery	Saudi Arabia	Rappaport-Vassilidis enrichment screened by PCR	8	0	0.0	[0, 26.2]	25 g	(Hassan et al., 2011)
Restaurants	Carrot juice	Mexico	NS	280	24	8.6	[5.7, 12.3]	NS	(Torres-Vitela et al., 2013)
Retail markets	Celery	USA	NS	12	0	0.0	[0, 18.5]	25 g	(Thunberg et al., 2002)
Central produce supply	Celery	Mexico	Enrichment in Rappaport-Vassiliadis broth and subcultured onto brilliant green, XLD and MacConkey's agars	100	3	3.0	[0.9, 7.8]	50 g	(Quiroz-Santiago et al., 2009)
Central produce supply	Onion	Mexico	Enrichment in Rappaport-Vassiliadis broth and subcultured onto brilliant green, XLD and MacConkey's agars	100	0	0.0	[0, 2.5]	50 g	(Quiroz-Santiago et al., 2009)
Markets	Stem and root vegetables[b]	Spain	Tetrathionate-Kauffman broth subcultured onto SS agar	204	5	2.5	[0.9, 5.3]	NS	(Garcia-Villanova Ruiz et al., 1987)
Wholesale and retail stores	Celery, carrots, radish or spinach	USA	Official Methods of Analysis 13th Ed	50[c]	4[c]	8.0 [c]	[2.8, 17.9]	NS	(Rude et al., 1984)
Retail	Celery (organic)	UK	PHLS (ISO 6579)	193	0	0.0	[0, 1.3]	25 g	(Sagoo et al., 2001)

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Sample size	Reference
Retail	Spring onions (organic)	UK	PHLS (ISO 6579)	87	0	0.0	[0, 2.8]	25 g	(Sagoo et al., 2001)
Retail	Carrots (organic)	UK	PHLS (ISO 6579)	478	0	0.0	[0, 0.5]	25 g	(Sagoo et al., 2001)
Import	Celery	USA from various countries	NS	84	1	1.2	[0.1, 5.4]	16 oz	(US-FDA, 2001)
Street vendors	Carrot	India	FOA, Manual of Food Quality Control	8	2	25.0	[5.6, 59.2]	25 g	(Viswanathan and Kaur, 2001)
Street vendors	Celery	India	FOA, Manual of Food Quality Control	8	5	25.0	[5.6, 59.2]	25 g	(Viswanathan and Kaur, 2001)

NS: not stated
(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).
(b): Garlic, sweet potato, onion, chive, mushroom, turnip, potato, leek, radish, beet and carrot.
(c): One sample of celery, carrot, radish and spinach. Denominators of each vegetable not stated.

8.2. *Yersinia*

8.2.1. Analytical methods for the detection and enumeration of *Yersinia* in bulb and stem vegetables and carrots

The genus *Yersinia* comprises three species, which are potentially pathogenic to humans: *Y. pestis*, *Y. pseudotuberculosis*, and *Y. enterocolitica*. Of these, *Y. enterocolitica* is most important as a cause of foodborne illness and serogroups that predominate in human illness are O:3, O:8, O:9, and O:5,27. *Y. pseudotuberculosis* is less ubiquitous than *Y. enterocolitica*, and although frequently associated with animals, has only rarely been isolated from soil, water, and foods. *Y. pestis* is not a foodborne pathogen: it is transmitted to its host via flea bites or via the respiratory route. Analytical methods for the detection of presumptive pathogenic *Y. enterocolitica* in food stuffs have been developed and adopted across laboratories testing food. The reference method for official controls includes the EN/ISO standard method 10273:2003.[17] The presence of pathogenic *Y. enterocolitica* is determined qualitatively by a combination of selective enrichment and subculture on selective agar media. Isolated presumptive colonies are purified and subsequently subjected to biochemical characterisation (enabling biotyping) and optional serological confirmation and pathogenicity testing (the mechanisms of pathogenicity of enteropathogenic *Yersinia* are complex and include a number of both chromosomally and plasmid determined factors). The isolation methods used for *Y. enterocolitica* are also used for *Y. pseudotuberculosis*, but are generally insufficient for the latter species as selective enrichment is inefficient for the recovery of this species (Niskanen et al., 2002; Laukkanen et al., 2008). As an alternative, real time PCR method for detection of pathogenic *Y. enterocolitica* and *Y. pseudotuberculosis* in food is also available (e.g. NMKL 163).[18]

8.2.2. Data on occurrence and levels of *Yersinia* on bulb and stem vegetables and carrots

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Yersinia* in the EU Member States and there are limited data on the occurrence of *Yersinia* in/on these vegetables in the peer-reviewed world literature (Table 4). Since only two studies were located in the EU there are limited data available from studies on the occurrence of *Yersinia* in/on these vegetables, and these studies are small (e.g. comprising < 32 samples). It is not possible to include occurrence data on the contamination of these vegetables by *Yersinia* within the zoonoses monitoring data (according to the Directive 2003/99/EC)[19] since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits. Consequently, there are difficulties in assessing the representativeness of these data to estimate the overall levels of contamination.

[17] EN/ISO 10273:2003. Microbiology of food and animal feeding stuffs - Horizontal method for the detection of presumptive pathogenic *Yersinia enterocolitica*. International Organization for Standardization, Geneva, Switzerland.

[18] NMKL 163:2013. Pathogenic *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* - real-time PCR methods for detection in food, feed and environmental samples. 2nd Edition.

[19] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 4: Occurrence of *Yersinia*. in bulb and stem vegetables and carrots

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Sample size	Reference
Retail supermarkets	Grated carrot	Spain	ISO 10273:2003 for *Yersinia enterocolitica*	18	0	0 (*Y. enterocolitica*)	[0, 12.9]	25 g	(Abadias et al., 2008)
Minimal processing plants	Washed whole, peeled, cut and grated carrots	Finland	ISO 10273:10273 with modifications (*Y. enterocolitica*) USFDA Bacteriological Analytical Manual (*Y. pseudotuberculosis*)	32	0	0 (*Y. pseudotuberculosis*)	[0, 7.5]	25 g	(Maatta et al., 2013)

NS: not stated
NA: not applicable
(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).

8.3. *Shigella*

8.3.1. Analytical methods for the detection and enumeration of *Shigella* in bulb and stem vegetables and carrots

The genus *Shigella* consists of four species: *S. dysenteriae* (subgroup A), *S. flexneri* (subgroup B), *S. boydii* (subgroup C), and *S. sonnei* (subgroup D) all of which cause human disease. *S. flexneri* and *S. sonnei* are most associated with food borne disease. *S. boydii* is infrequently identified as a foodborne pathogen. *Shigella* organisms may be very difficult to distinguish biochemically from *Escherichia coli.* As is the case for pathogenic *E. coli,* the virulence of *Shigella* is multifactorial, involving both chromosomal and plasmid genes with the essential role of a large plasmid involved allowing invasion (Binet and Lampel, 2013). ISO 21567:2004[20] specifies a horizontal method for the detection of *Shigella* species. The presence of *Shigella* can be determined qualitatively by a combination of selective enrichment and subculture on multiple selective agar media. Isolated presumptive colonies are purified and subsequently subjected to biochemical and serological confirmation. Reliable detection and isolation of *Shigella* from foods is challenging, due to the organism being easily overgrown by the competing microbiota (Uyttendaele et al., 2001). As an alternative, a real time PCR method for detection of *Shigella* in food is also available (e.g. NMKL 174).[21]

8.3.2. Data on occurrence and levels of *Shigella* on bulb and stem vegetables and carrots

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Shigella* in the EU Member States and there are limited data on the occurrence of *Shigella* in/on these vegetables in the peer-reviewed world literature (Table 5). There are limited data available from studies on the occurrence of *Shigella* in/on these vegetables, and some of these studies are small (e.g. comprising < 10 samples) with a variety of methods and sample sizes hence there are difficulties making meaningful comparisons between individual studies difficult and in establishing the representativeness of the data on occurrence of the bacterium. All samples were collected outside the EU. It is not possible to include occurrence data on contamination of these vegetables by *Shigella* within zoonoses monitoring data (according to the Directive 2003/99/EC)[22] since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits.

[20] EN/ISO 21567:2004. Microbiology of food and animal feeding stuffs - Horizontal method for the detection of *Shigella* spp. International Organization for Standardization, Geneva, Switzerland.
[21] NMKL 174:2002. *Shigella* spp. PCR method for detection in foods. 2nd Edition.
[22] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 5: Occurrence of *Shigella* in bulb and stem vegetables and carrots

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Sample size	Reference
Retail (distribution centres and markets)	Organic scallions and green onions	Canada	Health Canada Compendium of Analytical Methods MFLP-25	173	0	0	[0, 1.4]	25 g	(Arthur et al., 2007)
Retail markets and street vendors	Green onion	Saudi Arabia	AOAC Compendium of Methods for Microbiological examination of Foods 2001	6	0	0	[0, 33]	25 g	(Hassan et al., 2011)
Retail markets and street vendors	Celery	Saudi Arabia	AOAC Compendium of Methods for Microbiological examination of Foods 2001	8	0	0	[0, 26.2]	25 g	(Hassan et al., 2011)

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).

8.4. Norovirus

8.4.1. Analytical methods for the detection and enumeration of Norovirus in bulb and stem vegetables and carrots

Information on the standardisation of methods for detection of Norovirus in foods can be found in Section 4.3.2 of the scientific opinion of the EFSA Panel on Biological Hazards (BIOHAZ) (2011b).

There are two ISO/CEN methods[23] which are currently available for Norovirus detection and quantification, respectively, in food. These methods currently have the status of a Technical Specification (TS) and, based upon validation data, will need to be reviewed three years after initial publication before becoming a full International Standard.[24] The methods are technically complex, and their performance strictly according to their technical specifications can only be carried out in specialised and well-resourced laboratories with skilled personnel. In particular, the production of the nucleic acid controls is challenging, and the availability of reliable quality control materials and External Quality Assurance (EQA) schemes will be necessary before there can be complete confidence in the concordance of results between laboratories. These ISO/CEN methods are currently technical specifications and have the opportunity to be further refined with regard to sampling, sample preparation, limit of detection and interpretation of results. To date, there are few reports of analytical methods for Norovirus detection on bulb and stem vegetables (e.g. onion and garlic) and carrots. ISO/TS 15216-1 and ISO/TS 15216-2 refer to detection of Norovirus on leafy green vegetables and berry fruit. However, it should be possible to apply them to the detection of Norovirus on bulb and stem vegetables and carrots.

8.4.2. Data on occurrence and levels of Norovirus on bulb and stem vegetables and carrots

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of Norovirus in the EU Member States and there are limited data on the occurrence of Norovirus in/on these vegetables in the peer-reviewed world literature (Table 6). There are limited data available from studies on the occurrence of Norovirus in/on these vegetables, and all of these studies are small (e.g. comprising < 50 samples) with a variety of methods and sample sizes hence there are difficulties making meaningful comparisons between individual studies and in establishing the representativeness of the data on occurrence of the virus. All of the samples were collected outside the EU. It is not possible to include occurrence data on contamination of these vegetables by Norovirus within zoonoses monitoring data (according to the Directive 2003/99/EC)[25] since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits.

[23] ISO/TS 15216-1: Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 1: Method for quantification. International Organization for Standardization, Geneva, Switzerland.
ISO/TS 15216-2: Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 2: Method for qualitative detection. International Organization for Standardization, Geneva, Switzerland.

[24] International Organization for Standardization. ISO deliverables. ISO/TS technical specification. Available online: http://www.iso.org/iso/home/standards_development/deliverables-all.htm?type=ts

[25] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 6: Occurrence of Norovirus on bulb and stem vegetables and carrots

Sampling place	Commodity	Sampling country	Number of samples analysed	Number of samples where Norovirus detected	% of positive samples	95 % CI[(a)]	Reference
Farms	Green onions	Egypt	144	49	34.0	[26.7 ,42]	(El-Senousy et al., 2013)
Farms	Leek	Egypt	144	30	20.8	[14.8, 28]	(El-Senousy et al., 2013)
Market	Baby carrot	USA	31	3	9.7	[2.8, 23.6]	(Groman et al., 2010)
Market	Green onions	USA	21	1	4.7	[0.5, 20.2]	(Groman et al., 2010)
Market	Green onions	Malaysia	30	4	13.3	[4.7, 28.7]	(Noor Hidayah et al., 2011)
Catering	Green onions	Turkey	92	1	1.1	[0.1, 5]	(Yilmaz et al., 2011)

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).

The samples described in Table 6 were analysed in the course of four research surveys, none of which occurred in the EU. None of the foodstuffs sampled were known to be linked to any outbreaks. The analyses used methods similar to the standardised methods described in ISO/TS 15216-1 and ISO/TS 15216-2, in general or specific aspects.

Groman et al. (2010) surveyed produce items collected from 14 states in the USA, and found 3/31 baby carrot samples and 1/21 green onion samples to be contaminated with Norovirus GII. Analysing green onions from salad bars and restaurants in Istanbul, Yilmaz et al. (2011) found one sample contaminated with Norovirus GII out of the 93 tested. Noor Hidayah et al. (2011) found 4 samples (out of 30 tested) of green onion and one sample (out of 30 tested) of red onion obtained from a local market in Selangor, Malaysia, to be contaminated with Norovirus GI. El-Senousy et al. (2013) found 49/144 green onion samples collected from farms in the Nile Delta in Egypt to be contaminated with a mean of 5.6×10^{1} Norovirus GI, and 30/144 leek samples 37/144 radish samples from the same sources to be contaminated with a mean of 5.9×10^{1} Norovirus GI. The high prevalence of Norovirus contamination observed in this latter study was likely due to the water used for irrigation of the vegetables being drawn from contaminated river sources: the same study found 36/144 (25.0 %) of irrigation water samples from the farms to be positive for Norovirus GI (El-Senousy et al., 2013).

8.5. Conclusions

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Salmonella, Yersinia, Shigella* and Norovirus in the EU Member States and there is limited data on the occurrence of these pathogens in/on these vegetables in Europe. There are limited studies available in the peer-reviewed world literature on the occurrence of *Salmonella, Yersinia, Shigella and* Norovirus on/in bulb and stem vegetables or carrots. Hence, there are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

9. Mitigation options to reduce the risk to humans posed by *Salmonella, Yersinia, Shigella* or Norovirus contamination in bulb and stem vegetables and carrots

9.1. Introduction

Many of the mitigation options previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c) are generic and equally applicable to other foods of non-animal origin, including bulb and stem vegetables as well as carrots. However, there are some differences, inherent to bulb and stem vegetables as well as carrots, which are substantially different commodities than leafy greens with

respect to: (i) the production system (true bulbs and roots are normally formed underground although some plants such as garlic can also produce aerial small bulbs, or for green (immature) onions also the leaves can be used for consumption); (ii) often mechanical harvest occurs and thus there is little or no hand picking; (iii) their intrinsic characteristics (most of these vegetables have a quite robust peel or external protection against microbial contamination, for some antimicrobial activity has been described); (iv) a longer shelf life and prolonged stored postharvest is common either dried (e.g. onions) or kept in soil under humid conditions (carrots), and (v) epidemiological evidence associating their consumption with foodborne outbreaks is often linked to catering, restaurants or home consumption where these type of vegetables have been subject to extensive manual handling in preparation of ready-to-eat fresh-cut or grated raw vegetables in salad bars.

9.2. General mitigation options

Appropriate implementation of food safety management systems including Good Agricultural practices (GAP), Good Hygienic Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing bulb and stem vegetables as well as carrots. These food safety management systems should be implemented along the farm to fork continuum and should be applicable to the control of a range of microbiological hazards. Although some intervention strategies or control measures can be defined to prevent, limit the spread or sometimes reduce the level of contamination, the main focus for food safety management should be on preventive measures, as it is difficult to define critical control points (CCPs) that either eliminate the microbial hazard or significantly reduce it. Codes of practice and guidelines should encourage the use of appropriate good agricultural and hygiene practices at farm level. Food safety management based upon GMP and HACCP principles should be the objective of processors, distributors, retailers and caterers involved in production of bulb and stem vegetables and carrots. In addition, the responsibilities of the food business operators producing or harvesting plant products require them to take adequate control measures as outlined in Regulation (EC) No 852/2004[26] and these are identical to those outlined previously (EFSA BIOHAZ Panel, 2014c). Where practicable, a comprehensive food safety control plan that includes a written description of each of the hazards identified in assessing environmental hygiene and the steps to be implemented to address each hazard should be prepared at primary production (EFSA BIOHAZ Panel, 2014c), and there should be complete traceability through primary production, processing, distribution, retail, and catering, up to consumption of all products. Mitigation options through compliance with existing prerequisite programs such as GAP and GMP, and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, should assist in reducing risks of contamination by *Salmonella, Shigella, Yersinia* and Norovirus.

9.2.1. Environment

As outlined with leafy greens (EFSA BIOHAZ Panel, 2014c), primary production should not be carried out in growing areas where the known or presumptive presence of pathogens would lead to an unacceptable likelihood of transfer to horticultural crops intended for human consumption without a validated process kill step (CAC, 1969, 2003) which includes bulb and stem vegetables as well as carrots which are eaten raw or minimally processed. Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, in the event of heavy rainfall and flooding for example, intervention strategies should be applied to restrict growers from using this land for production of these vegetables until the hazards have been addressed. Preventive measures are not always easy to implement as farmers may not control adjacent land activities, or the land history does not include knowledge of the level of pathogens in the soil or the time taken to reduce these to acceptable levels (Suslow et al., 2003; James, 2006; Gil et al., 2015).

[26] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.

Bulb and stem vegetables as well as carrots are likely to be in direct contact with soil during growth and/or harvesting. Bird droppings and airborne contaminants (nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contamination. Domestic and wild animals should be excluded from production areas, to the extent possible, using appropriate biological, cultivation, physical and chemical pest control methods.

9.2.2. Manure, sewage and sewage sludge

Appropriate production, storage, management and use of manure or sludge is equally important for bulb and stem vegetable production as well as carrot production to reduce residual pathogen populations as outlined for leafy greens (EFSA BIOHAZ Panel, 2014c) and treatment procedures to reduce or eliminate pathogens from contaminated manure are, as with any ready-to-eat food, equally applicable. The same consideration for the use of organic amendments previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c) also apply to production of these vegetables.

9.2.3. Water

Although, bulb and stem vegetables are usually cultivated with the use of natural rainfall, artificial irrigation is sometimes used and it is important to select appropriate irrigation sources and avoid, if possible, uncontrolled sources of water such as rivers and lakes as was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c). Since bulb and stem vegetables can be intended for direct consumption, for washing (if applicable), clean or potable water is recommended for use. It is recommended that the quality of the water used in packing establishments be controlled and monitored, i.e. recording testing for indicator organisms and/or foodborne pathogens and, if necessary, treated before use.

9.2.3.1. Water in primary production

Risks can be minimised by growers identifying the sources of water used on the farm (municipality, re-used, irrigation water, reclaimed wastewater, discharge water from aquaculture, well, open canal, reservoir, rivers, lakes, farm ponds, etc.) and identifying vulnerabilities to faecal contamination. Attention should be paid to the selection of the water sources for irrigation, agricultural chemical application (e.g. fungicide) and in particular to the avoidance of the use or the ingress of water contaminated by human sewage or faecal wastes from other animals.

Among the potential interventions, both water treatment or efficient drainage systems that take up excess overflows are needed to prevent the additional dissemination of contaminated water. The risks posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm for the presence of pathogens. This should include a documented check detailing the potential for microbial contamination from all possible human and/or animal faecal sources of contamination (e.g. from animals, human habitation, leaks from on-field sanitary facilities, promiscuous defecation in production environments, sewage treatment, manure and composting operations) and the water's suitability for its intended use. In the case of identified contamination sources of the water used on the farm, corrective actions should be taken to minimize the risk of exposure to the carrots, bulb and stem vegetables. The effectiveness of corrective actions should be verified. Identifying and implementing corrective actions is a means to prevent or minimize contamination of water for primary production (e.g. settling or holding ponds that are used for subsequent irrigation and/or harvesting may attract animals or in other ways increase the microbial risks associated with water for irrigation). Possible corrective actions may include fencing to prevent large animal contact, proper maintenance of wells, filtering water, not stirring the sediment when drawing water, building settling or holding ponds, and water treatment facilities and water treatment. Since *E. coli* is an indicator micro-organism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures. Additional analytical testing may be necessary after a change in irrigation water source, flooding or a heavy rainfall when water is at a higher risk of contamination.

9.2.3.2. Process wash water

Mitigation strategies aiming to reduce risks of microbial contamination and cross-contamination for all water used during minimal processing were previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014c). Potable water should be used during minimal processing and this should include wash-water where used, as well as that used for hydro-cooling, or other uses. To maintain the microbial quality of the water and avoiding cross-contamination in a washing tank, the use of disinfectant agents is recommended. Disinfection solutions should be monitored to ensure that the disinfectant is present at sufficient levels to achieve its intended purpose reducing the potential for cross-contamination (without generation of chemical by-products).

Water that is used in hydro-coolers should be of potable quality. Water that is used only once and not recirculated is preferable. If water is used for cooling and is recirculated, it should be evaluated and monitored to ensure that disinfectant levels, if used, are sufficient to reduce the potential risk of cross-contamination (without generation of chemical by-products).

9.2.4. Equipment

The adherence to adequate cleaning and disinfection of equipment used in harvest and postharvest sorting, packing or further minimal processing is an important preventive measure to avoid microbial contamination of equipment as was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014c) and similar considerations apply to bulb and stem vegetables and carrots production and minimal processing. Growers should ensure that clean pallets and containers (disinfected where necessary) are used, and take measures to ensure that the containers do not come into contact with unprocessed manure or other sources of cross-contamination.

If these vegetables pass over brushes in either dry or wet cleaning, care should be taken to ensure they do not damage or result in cross-contamination, and these brushes should be routinely inspected, cleaned and adjusted as needed.

Cooling equipment should be cleaned and disinfected on a regular basis according to written procedures to ensure that the potential for cross-contamination is minimized.

Handling of bulb and stem vegetables may include harvest, transport to packing house, curing and storage such as the case of onions, washing, sorting and grading, hydro-cooling and packaging (Garrett et al., 2003). Bulb and stem vegetables and carrots should be washed with potable water before cutting or peeling (if appropriate to the process), although some, like onions, can be dry peeled. Cutting or peeling knife blades should be cleaned and disinfected on a regular basis according to written procedures to reduce the potential for cross-contamination during the cutting or peeling process.

Before cutting or other minimal processing, a further reduction in microbial contamination may be achieved by scrubbing in the presence of a sanitizer or application of an alternative surface decontamination process such as hot water, steam or other treatments. Knife blade disinfection solutions should be monitored to ensure that the disinfectant is present at sufficient levels to achieve its intended purpose and does not promote the potential for cross-contamination.

9.2.5. Training and education of workers

The importance of standard enforceable policies and provision of training in sanitation for all employees working in primary production, minimal processing, retail and catering was emphasised for leafy greens (EFSA BIOHAZ Panel, 2014c). Compliance with hygiene requirements, in particular hand hygiene, is an absolute necessity for food handlers at all stages of the production and supply chain of bulb and stem vegetable as well as carrots to reduce the risks of *Salmonella*, *Shigella* and Norovirus contamination but is also to be taken into consideration for controlling *Yersinia*. Only workers who have been trained in hygienic handling should be assigned to pick, pack or process these vegetables. All persons involved in handling (cutting, grating, dicing, etc.) of bulb and stem vegetables

as well as carrots for buffets in catering and restaurants should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

9.2.6. Final product

Since *Salmonella, Shigella*, *Yersinia* and Norovirus are able to survive on intact bulb and stem vegetable as well as carrots from days to several weeks at both ambient and refrigeration temperatures, and may grow and penetrate into wounded tissues as well as on cut vegetables, adequate storage conditions should be applied to these products.

For bulb and stem vegetables and carrots normally stored at ambient temperature in a dry environment, such as mature bulbs of onions and garlic bulbs, consumers should be aware that cuts, slices of these vegetables or preparation of these vegetables such as sauces, pastes and pesto may support growth of foodborne pathogenic bacteria and should be kept refrigerated for no more than a few days.

Consumers need to be advised on how to handle, prepare, and store bulb and stem vegetables as well as carrots safely (preferably in a cool environment) and to avoid cross-contamination with foodborne pathogens from various sources (e.g. hands, sinks, cutting boards, utensils, raw meats). They should also be given guidance on correct hand washing methods, and the need to properly peel or wash carrots and bulb and stem vegetables with potable water before consumption.

As bulb and stem vegetables come from soil or have been in close contact with soil, and can be stored for extended periods before retail sale, consumers should be advised to wash and/or scrub whole or peeled (whatever appropriate) bulb and stem vegetables as well as carrots using potable running water and, where appropriate, disinfectant solutions before consumption. Pre-cut products should not be rewashed. It is recommended that pre-cut carrots and other bulb and stem vegetables should be wrapped/packaged and refrigerated as soon as possible and distributed and kept under refrigeration temperatures.

9.2.7. Conclusions

Compliance with existing prerequisite programs such as Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP), and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, will assist *Salmonella, Shigella, Yersinia* and Norovirus risk mitigation strategies in primary production.

Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, in the event of heavy rainfall and flooding for example, intervention strategies should be applied to restrict growers from using this land for production of these vegetables until the hazards have been addressed.

Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near bulb and stem vegetables as well as carrot growing areas.

Attention should be paid to the selection of the water sources for irrigation, agricultural chemical application (e.g. fungicide) and in particular to the avoidance of the use or the ingress of water contaminated by sewage.

Both water treatment and efficient drainage systems that take up excess overflows are possible mitigation options to prevent the additional dissemination of contaminated water. The risks posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm

for the presence of pathogens. Since *E. coli* is an indicator micro-organism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures. Appropriate production, treatment, storage, management and use of manure or sludge are important.

During minimal processing GMP and food safety management systems (including HACCP) will assist *Salmonella, Yersinia, Shigella* and Norovirus risk mitigation strategies.

It is recommended that water used during minimal processing be monitored to assess its microbial quality. When disinfectants are used in wash water, the concentration should be monitored to verify that they are applied effectively to reduce the potential risk of cross-contamination while avoiding the accumulation of disinfection by-products.

Furthermore, the main mitigation options for reducing the risk of pathogens' contamination on bulb and stem vegetables and carrots includes scrupulous adherence to hand hygiene by food handlers at all stages of the supply chain. Employees with symptoms of gastroenteritis should be excluded from working in food production (i.e. including harvesting and minimal processing) until their symptoms have subsided.

The equipment should be cleaned and disinfected on a regular basis according to written procedures to ensure that the potential for cross-contamination is minimized.

All persons involved in handling (cutting, grating, dicing, etc.) of bulb and stem vegetables as well as carrots for buffets in catering and restaurants should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

Information should be provided to consumers on appropriate handling of bulb and stem vegetables and carrots, which should include specific directions for product storage, preparation and intended use. Consumers should be informed if bulb and stem vegetables as well as carrots are intended to be consumed as ready-to-eat, and to wash and/or scrub whole or peeled products using potable running water when appropriate.

9.3. Specific mitigation options to reduce the risk of *Salmonella* and *Yersinia* contamination

As previously considered for leafy greens (EFSA BIOHAZ Panel, 2014c), *Salmonella* have their reservoirs in domestic as well as wild animals, birds and humans. The main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots are consequently to prevent direct contact with animal, bird or human faeces as well as indirect contact through slurries, sewage, sewage sludge, contaminated soil, water, equipment or food contact surfaces or food handlers.

Yersinia enterocolitica and *Y. pseudotuberculosis* have their reservoirs in the intestinal contents of a range of animals and are commonly isolated from different environments contaminated by faeces. As with *Salmonella*, the main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots by *Yersinia* are consequently to prevent direct contact with animal or human faeces as well as indirect contact through slurries, sewage, sewage sludge, contaminated soil, water, equipment or food contact surfaces as well as food handlers. Access of wild animals, such as birds or rodents should be prevented from premises used for post-harvest processes and storage as is likely to have occurred in outbreaks in Finland (Kangas et al., 2008).

At primary production, assessment of risks for *Salmonella* as well as *Yersinia* contamination from the environment should aim to reduce risks from previous cultivation or adjacent land use (particularly when associated with domestic animal production) as well as attractants and harbourage of wild animals and pests. Particular attention should be paid to appropriate treatment, storage and application of organic amendments, if used, since these bacteria survive in water, including the possibility of contaminating water used for irrigation. Care should also be taken to prevent the use of equipment

contaminated with *Salmonella and Yersinia*, particularly segregation from equipment that has come into contact with animals. Persons handling food during harvesting (as well as during subsequent minimal processing) are a potential source of *Salmonella* or *Yersinia* contamination, and adequate toilet and hand-washing facilities must be provided at production areas. Scrupulous compliance with hand hygiene practices such as effective washing is an absolute necessity for all food supply chain employees, and should be emphasised in local codes of practice and training manuals. Persons with symptoms of gastroenteritis should be excluded from handling foodstuffs at all stages.

During minimal processing, cooling and washing, all necessary steps to prevent contamination by *Salmonella* and *Yersinia* should be carried out, however these processes, at best, are aimed at preventing contamination or subsequent growth. Where contamination has occurred at primary production, even with adequately operated and monitored washing procedures, at best only a 1-2 log unit reduction is likely to be achieved in the final product. Carrots can be stored at cold temperatures for several months in high humidity. Decaying carrots are likely to be a substrate for growth of *Y. enterocolitica* and *Y. pseudotuberculosis*. Processors or caterers should not use poor quality carrots.

During distribution, retail, catering and handling in domestic environments, all reasonable steps should be taken to prevent cross-contamination of *Salmonella* and *Yersinia* from other foods, as well as from food handlers.

As stated previously for leafy greens (EFSA BIOHAZ Panel, 2014c) washing alone will have some effect in reducing the microbiological (including pathogen) biota whilst also having the potential for cross-contamination, and identical effects for bulb and stem vegetables and carrots will occur. Washing with water alone is likely to result in reductions of about 1 log cfu/g of *Salmonella* and *Yersinia* and the use of sanitizers will have an effect on surface contamination by pathogens (as well as the microbiota); however, this will not guarantee elimination of bacterial foodborne pathogens. Various sanitizers and other treatments have been evaluated for treating bulb and stem vegetables and carrots for reducing *Salmonella* contamination, and these are generally of experimental nature and provide a low strength of evidence. These treatments included: chlorine and peroxyacetic acid (Ge et al., 2013); electrolyzed water (Abadias et al., 2008; Park et al., 2008, 2009); ozonated water (Xu and Wu, 2014); irradiation (Lopez et al., 2005; Dhokane et al., 2006; Song et al., 2006; Murugesan et al., 2011; Ndoti-Nembe et al., 2013); thermoultrasound and calcium propionate (Kwak et al., 2011); dense phase carbon dioxide (Liao et al., 2010); essential oils and bacteriocins (Ndoti-Nembe et al., 2013); high hydrostatic pressure (Nettoo et al., 2011, 2012); carvacrol and cinnamaldehyde (Ravishankar et al., 2010); and gaseous chlorine dioxide (Sy et al., 2005).

There is no specific information available on the effects of sanitizers and other treatments for reducing *Yersinia* in bulb or stem vegetables or carrots.

9.4. Specific mitigation options to reduce the risk of *Shigella* and Norovirus contamination

Both Norovirus and *Shigella* have their reservoir in humans. Therefore, the main mitigation options are good personal hygiene practices by food handlers during harvest, when manually handling produce during sorting, packing and at the point of final preparation and food service. In addition, mitigation options include prevention of contamination from other food types as well as food contact surfaces. As Norovirus as well as *Shigella* have no proven zoonotic reservoirs, the main sources within the environment from which contamination of food by Norovirus or *Shigella* can arise include sewage-contaminated water and sewage sludge. Hence, at primary production avoiding the use of sewage-contaminated water and inadequately treated sewage sludge are the main mitigation options for reducing the risk of Norovirus and *Shigella* contamination of these vegetables. In contrast to Norovirus, which may persist for prolonged periods of time in the environment, *Shigella* cells are, once excreted from the human host, quite sensitive to environmental conditions and may die rapidly, especially when exposed to direct sunlight or drying (Binet and Lampel, 2013).

As was discussed previously for tomato production (EFSA BIOHAZ Panel, 2014d), information on existing preventive measures suitable for controlling Norovirus contamination which are in place according to current EU legislation, and control options for FoNAO can be found in Sections 6.2 of the scientific opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011a), and in the Codex Guidelines on the application of general principles of food hygiene to the control of virus contamination of food (CAC, 2012). The available guidance is general and does not refer specifically to individual food commodities such as bulb and stem vegetables or carrots, although Annex 2 "Control of hepatitis A and Norovirus in fresh produce" of the Codex Guidelines should be directly applicable to these food categories. The same information may be applicable for the prevention of *Shigella* contamination.

Overall it is recommended that only clean or potable water be used during production and minimal processing, and corrective actions should be taken if contamination occurs. Possible corrective actions include disinfection e.g. by chlorine. The equipment that comes in contact with food should be effectively cleaned and, where necessary, disinfected. The efficacy of currently available water and surface disinfection treatments against Norovirus is not fully certain, and EFSA has recommended (EFSA Panel on Biological Hazards (BIOHAZ), 2011b) that effort should be focussed on avoiding viral contamination rather than trying to remove/inactivate viruses in food. *Shigella* are quite susceptible to conventional disinfection treatments, therefore prevention of *Shigella* contamination by adherence to good hygienic practices in primary production, minimal processing and preparation are recommended.

Employees with symptoms of gastroenteritis should be excluded from working in food production (i.e. including harvesting and minimal processing) until their symptoms have subsided, e.g. for 48 hours. However, as pre- and post-symptomatic shedding can occur, this exclusion may not be entirely sufficient to prevent the possibility of food contamination from occurring, and returning employees should pay special attention to hand hygiene. Scrupulous compliance with hand hygiene practices such as effective washing is an absolute necessity for all food supply chain employees, and should be emphasised in local codes of practice and training manuals, both in developed and developing countries.

Wang et al. (2013b) investigated the physical removal of Murine Norovirus, a human Norovirus surrogate, from contaminated produce items including carrots and celery by scrubbing under running water with a nylon brush or scouring pad and by peeling. The degree and extent of utensil contamination with viruses during these operations in the presence and absence of food residue was also investigated. Scrubbing or peeling resulted in significant levels of virus removal, ranging from 0.93 to 2.85 log PFU. However, utensil cross-contamination occurred and after preparation of a contaminated produce item, utensil cross-contamination resulted in virus detection on seven successively prepared produce items. Thus, scrubbing and peeling produce can reduce levels of viruses on contaminated produce, but the importance of utensil sanitation to prevent cross-contamination is highlighted.

Green onions inoculated with human NoV surrogates were treated with UV (240 mJ s/cm^2), ozone (6.25 ppm for 10 min), pressure (500 MPa, for 5 min at 20 °C), or sprayed with calcium hypochlorite (150 ppm, 4 °C). Both Murine Norovirus (MNV) and human adenovirus type 41 (Ad41) were inoculated either on the surface through spot inoculation or through inoculating contaminated hydroponic solution allowing for uptake of the virus into the internal tissues. Both surface inoculated viruses and viruses internalized in green onions were inactivated to some extent by these post-harvest minimal processing treatments. Viral inactivation for both surrogate viruses was greatest after pressure treatment, followed by ozone treatment, and the lowest inactivation was observed after chlorine and UV treatment (Hirneisen and Kniel, 2013b). It has been shown that treatment of green onions inoculated with MNV with ozone (6.25 ppm) achieved a > 2-log reduction was after 1 min of ozone treatment (Hirneisen et al., 2011).

10. Data on occurrence of *E. coli* on bulb and stem vegetables and carrots and use of E. *coli* as an indicator

There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *E. coli* in the EU Member States and there are limited data on the occurrence of *E. coli* in/on these vegetables in the peer-reviewed world literature (Table 7). There are limited data available from studies on the occurrence of *E. coli* in/on these vegetables, and some of these studies are small (e.g. comprising < 20 samples) with a variety of methods and sample sizes hence there are difficulties making meaningful comparisons between individual studies difficult and in establishing the representativeness of the data on occurrence of the bacterium. Some of the samples were collected outside the EU. Consequently there are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

Since there is a lack of data on the occurrence and levels of *E. coli* in bulb and stem vegetables as well as carrots, it is not currently possible to establish relationships between production and minimal processing practices and numbers of *E. coli.* However, as previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014c), *E. coli* is commonly present in faecal material and has general use as a hygiene indicator. Consequently, because *E. coli* is present in high numbers in faecal material (*e.g.* fresh manure) and likely to decline in the soil and on the surfaces of bulb and stem vegetables as well as carrots during primary production, it can be considered as an indicator of a recent exposure to risk factors for *Salmonella* as well as for *Shigella* and *Yersinia*. However, there is currently insufficient available data to assess the effectiveness of *E. coli* criteria to verify compliance to Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and food safety managements systems (including HACCP) in the production and minimal processing of bulb and stem vegetables as well as carrots.

11. Microbiological criteria for bulb and stem vegetables and carrots

Considering the limited evidence for both the occurrence and public health risks from contamination of *Salmonella, Shigella, Yersinia* and Norovirus in the primary production and minimal processing of bulb and stem vegetables and carrots, no conclusions can be made on the impact of the establishment of microbiological Hygiene Criteria, Process Hygiene Criteria or Food Safety Criteria on public health. However, it is still important that the mitigation options mentioned in Section 9 (including general hygiene rules and food safety management systems) are applied in order to avoid bulb and stem vegetables and carrots becoming vehicles of transmission of both zoonotic and non-zoonotic pathogenic micro-organisms to humans.

Table 7: Occurrence of *Escherichia coli* in bulb and stem vegetables and carrots

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Detection limit	*E. coli* levels	Reference
Retail (distribution centres and markets)	Scallions and green onions	Canada	Petrifilm	173	11	6.4	[3.4, 10.7]	<5 cfu/g	<5-7.600 cfu/g	(Arthur et al., 2007)
Retail	Pre-packed crudités	UK	BS 4285, violet red bile agar pour plate	247	33	13	[9.6, 18]	<1cfu/g	13% >1cfu/g ; 4% >10 cfu/g ; 2% >10^2 cfu/g	(Liitle et al., 1997)
Retail supermarkets	Grated carrot	Spain	ISO 7251:2005[(b)] MPN	18	0	0	[0, 12.9]	MPN	NA	(Abadias et al., 2008)
Retail farmer's markets	Carrots	Canada	Health Canada MFHPB-19 MPN	206	9	4.4	[2.2, 7.8]	MPN	Mean 1.21 log mpn/g	(Bohaychuk et al., 2009)
Retail farmer's markets	Green onions	Canada	Health Canada MFHPB-19 MPN	129	7	5.4	[2.5, 10.4]	MPN	Mean 1.43 log mpn/g	(Bohaychuk et al., 2009)
Retail markets and street vendors	Green onion	Saudi Arabia	Eosin methylene blue agar (AOAC Compendium of Methods for Microbiological examination of Foods 2001)	6	0	0	[0, 33]	NA	NA	(Hassan et al., 2011)
Retail markets and street vendors	Celery	Saudi Arabia	Eosin methylene blue agar (AOAC Compendium of Methods for Microbiological examination of Foods 2001)	8	1	12.5	[1.4, 45.4]	NS	Mean = 1 log cfu/g	(Hassan et al., 2011)
Minimal processing plants	Washed whole, peeled, cut and grated carrots	Finland	Violet red bile agar surface plate	32	0	0	[0, 7.5]	<1 cfu/g	NA	(Maatta et al., 2013)
Restaurants	Carrot juice	Mexico	NS	280	152	54.3	[48.4, 60.1]	3 MPN/ml	<3-460 MPN/ml	(Torres-Vitela et al., 2013)
Retail markets	Celery	USA	MPN	10	0	0	[0, 21.7]	NS	NA	(Thunberg et al., 2002)

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).
(b): ISO 7251:2005: Microbiology of food and animal feeding stuffs - Horizontal method for the detection and enumeration of presumptive *Escherichia coli* - Most probable number technique. International Organization for Standardization, Geneva, Switzerland.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Bulb and stem vegetables, for the scope of this scientific opinion, are defined according to commercial production and consumption and correspond to the botanically true bulbs of onions (*Allium cepa* L., *Allium fistulosum* L.), shallot (*Allium cepa* L.), the composite bulb of garlic (*Allium sativum* L.); the bundle of leaf sheath of the leek (*Allium ampeloprasum* L.); the bulb-like fleshy petioles bases of the Florence fennel (*Foeniculum vulgare* Mill.); the young shoots of asparagus (*Asparagus officinalis* L.); the fleshy petiole of celery (*Apium graveolens* L.).
- Carrots (*Daucus carota* L.), for the scope of this opinion, are defined according to commercial production and consumption as a root vegetable commonly orange.
- Emphasis is given here to vegetable types associated with public health risks, i.e. carrots, onion and garlic.
- Bulb and stem vegetables as well as carrots may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, cutting, packaging and storage. Other types of minimal processing (e.g. commercial unpasteurized juicing etc.) rarely occur outside retail and catering. Freezing may take place, but this will typically involve a heat blanching process and is outside the scope of this opinion, although frozen sliced onion may not be blanched.
- Bulb and stem vegetables as well as carrots may be subject to cooking, drying, bottling, canning and other processes but these are also outside the scope of this opinion.
- Despite the variety of types of bulb and stem vegetables as well as carrots produced and consumed, there is very little or no specific information for interactions with, risk factors, mitigation options and occurrence of *Salmonella, Yersinia, Shigella* or Norovirus. Most information is available for *Salmonella* and carrots, although this is very limited. Consequently, in addition to the limited data, conclusions are drawn through what is generally understood about the properties of these pathogens as well as information from other fresh produce.
- Onion, garlic and carrots grow in the soil and stem vegetables such as celery have prolonged direct contact with soil during growth and/or harvesting, particularly when celery is blanched.
- When consumed as ready-to-eat or minimally processed products, these vegetables are normally not subjected to physical interventions that will eliminate the occurrence of these pathogens.

Answers to the Terms of Reference

TOR 3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

- The risk factors at primary production for the contamination of bulb and stem vegetables as well as carrots with *Salmonella, Yersinia, Shigella* and Norovirus are poorly documented in the literature, with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce:
    - environmental factors, in particular proximity to animal-rearing operation and climatic conditions that increase the transfer to pathogens from their reservoirs to the bulb and stem vegetables and carrot growing areas;

- animal reservoirs (domestic or wild life) gaining access to growing areas for bulb and stem vegetables or carrots;
- contamination or cross-contamination by equipment at harvest or post-harvest, and by manipulation by workers if this takes place at primary production;
- use of untreated or insufficiently treated organic amendments;
- use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as pesticides.

- Processes at primary production which wet the external portions of the crop close to harvest represent the highest risk and these include spraying prior to harvest, direct application of fungicides and other agricultural chemicals and overhead irrigation.
- During minimal processing, contamination or cross-contamination via equipment, water or food handlers are likely to be the main risk factors for contamination with *Salmonella, Yersinia, Shigella* and Norovirus of bulb and stem vegetables as well as carrots.
- There is limited information on the behaviour of *Salmonella, Yersinia, Shigella* or Norovirus in the specific vegetable food matrices but these pathogens are likely to survive on the surfaces of these vegetables for days to several weeks at both ambient and at refrigeration temperatures.
- At distribution, retail and catering and in domestic and commercial environments, contamination and cross-contamination, in particular via direct or indirect contact between raw contaminated food and bulb and stem vegetables is a risk factor for *Salmonella, Yersinia, Shigella* and Norovirus. Cross-contamination risks include salad bar environments.
- At distribution, retail, catering and in domestic or commercial environments, infected food handlers are also risk factors (particularly for Norovirus and *Shigella*). Contamination can be direct or indirect via poor hand hygiene or food contact surfaces. These contamination and cross-contamination risks include salad bar environments.

TOR 4. To recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

- Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing bulb and stem vegetables as well as carrots. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of microbiological hazards.
- *Salmonella* have their reservoirs in domestic as well as wild animals, birds and humans. The main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots are consequently to prevent direct contact with animal, bird or human faeces as well as indirect contact through slurries, sewage, sewage sludge, contaminated soil, water, equipment or food contact surfaces or food handlers.
- *Yersinia enterocolitica* and *Yersinia pseudotuberculosis* have their reservoirs in the intestinal contents of a range of animals and are commonly isolated from different environments contaminated by faeces. The main mitigation options for reducing the risk of contamination of bulb and stem vegetables as well as carrots by *Yersinia* are consequently to prevent direct contact with animal or human faeces as well as indirect contact through slurries, sewage,

sewage sludge, contaminated soil, water, equipment or food contact surfaces as well as food handlers.

- Both Norovirus and *Shigella* have their reservoirs in humans. Therefore, the main mitigation options are good personal hygiene practices by food handlers during harvest, manual handling during sorting, packing and at the point of final preparation and food service. In addition, mitigation options include prevention of cross-contamination from other food types as well as food contact surfaces.

- The main sources within the environment from which contamination of food by Norovirus or *Shigella* can arise include sewage-contaminated water and sewage sludge. Hence, at primary production avoiding the use of sewage-contaminated water and inadequately treated sewage sludge, are the main mitigation options for reducing the risk of Norovirus and *Shigella* contamination of these vegetables.

- Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, in the event of heavy rainfall and flooding for example, intervention strategies should be applied to restrict growers from using this land for production of these vegetables until the hazards have been addressed.

- Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near bulb and stem vegetables as well as carrot growing areas.

- Attention should be paid to the selection of the water sources for irrigation, agricultural chemical application (e.g. fungicide) and in particular to the avoidance of the use or the ingress of water contaminated by sewage.

- Both water treatment or efficient drainage systems that take up excess overflows are possible mitigation options to prevent the additional dissemination of contaminated water.

- Risks posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm for the presence of pathogens. Since *Escherichia coli* is an indicator micro-organism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures.

- Appropriate production, treatment, storage, management and use of manure or sludge is important.

- During minimal processing, GMP and food safety management systems (including HACCP) will assist *Salmonella, Yersinia, Shigella* and Norovirus risk mitigation strategies.

- It is recommended that water used during minimal processing be monitored to assess its microbial quality.

- When disinfectants are used in wash water the concentration should be monitored to verify that they are applied effectively to reduce the potential risk of cross-contamination while avoiding the accumulation of disinfection by-products.

- The main mitigation options for reducing the risk of pathogen contamination of bulb and stem vegetables and carrots during minimal processing includes scrupulous adherence to hand

hygiene by food handlers at all stages of the supply chain. Employees with symptoms of gastroenteritis should be excluded from working in food production (i.e. including harvesting and minimal processing) until their symptoms have subsided.

- Equipment should be cleaned and disinfected on a regular basis according to written procedures to ensure that the potential for cross-contamination is minimized.

- All persons involved in handling (cutting, grating, dicing, etc.) of bulb and stem vegetables as well as carrots for buffets in catering and restaurants should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

- Information should be provided to consumers on appropriate handling of bulb and stem vegetables and carrots, which should include specific directions for product storage, preparation and intended use.

- Consumers should be informed if bulb and stem vegetables as well as carrots are intended to be consumed as ready-to-eat, and, to scrub whole or peeled products using potable running water when appropriate.

TOR 5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

- There is no routine or regular monitoring of bulb and stem vegetables or carrots for the presence of *Salmonella, Yersinia, Shigella and* Norovirus in the EU Member States and there are limited data on the occurrence of these pathogens in/on these vegetables in Europe.

- There are limited studies available in the peer-reviewed world literature on the occurrence of *Salmonella, Yersinia, Shigella and* Norovirus on/in bulb and stem vegetables or carrots. There are difficulties in making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

- Considering the limited evidence for both the occurrence and public health risks from contamination of *Salmonella, Shigella, Yersinia* and Norovirus in the primary production and minimal processing of bulb and stem vegetables and carrots, no conclusions can be made on the impact of the establishment of microbiological Hygiene Criteria, Process Hygiene Criteria or Food Safety Criteria on public health.

- There is a lack of data on the occurrence and levels of *E. coli* in bulb and stem vegetables as well as carrots. Thus, the effectiveness of *E. coli* criteria to verify compliance to Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and food safety management systems (including HACCP) in the production and minimal processing of bulb and stem vegetables as well as carrots cannot be assessed.

RECOMMENDATIONS

- More detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA's zoonoses database on occurrence and enumeration of foodborne pathogens.

- If additional biological hazards or further public health risks are identified with the consumption of these categories of food of non-animal origin, risk assessment studies may be needed to inform the level of hazard control that should be achieved at different stages of the food chain. These studies should be supported by targeted surveys on the occurrence of foodborne pathogens in such vegetables at specific steps in the food chain to indicate the level

of hazard control and efficacy of application of food safety management systems, including GAP, GHP, GMP and HACCP, that can be achieved.

- Further data should be collected to evaluate the suitability of microbiological (e.g. *E. coli)* indicators for relevant microbiological hazards in bulb and stem vegetables and carrots during their production and minimal processing.

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APPENDICES

Appendix A. List of questions to be addressed by the European Fresh Produce Association (Freshfel) and information received from Freshfel on 22 July 2013 and 19 August 2014

1. How do you categorise 'bulb and stem vegetables' and carrots according to different:
   - production systems,
   - processing (excluding thermal treatment or any equivalent (e.g. blanching as well as shelf stable juices) and
   - presentation at retail?

All questions below aim at characterizing the 'bulb and stem vegetables' and carrots sector in the EU.

PRODUCTION SECTOR

2. Provide an overview of this sector listing the most commonly produced botanical varieties of 'bulb and stem vegetables' in the EU?
3. Which are the top 10 types of 'bulb and stem vegetables' produced in EU including carrots?
4. Which are the top 10 types of 'bulb and stem vegetables' sold in EU including carrots?
5. Which countries are the major producers in the EU?
6. Which are the main third countries providing the EU with 'bulb and stem vegetables' and carrots?
7. Which is the share of the market covered by imported production versus intra-EU production of 'bulb and stem vegetables' and carrots?
8. What is the share of producers of 'bulb and stem vegetables' and carrots which are not members of Freshfel in the EU?
   Which volume of production do these producers represent?
9. Are there any figures in the EU to characterize the proportion of the production of 'bulb and stem vegetables' and carrots from "home/small scale" producers when compared to "large-scale" production?
10. Provide available figures on (i) production, (ii) producers, (iii) trade, (iv) certification and (v) distribution (type of outlets) of the 'bulb and stem vegetables' and carrots.
11. Indicate, if available the proportion of carrots sold peeled, pre-cut, shredded or whole?

AGRICULTURAL PRODUCTION SYSTEMS

12. Are there any producer's survey results which could help to describe how 'bulb and stem vegetables' and carrots are produced in the EU?
13. Characterise the profile of workers in the production of 'bulb and stem vegetables' and carrots (e.g. training, casual workers, foreign workers etc).
14. Please indicate percentages of production of 'bulb and stem vegetables' and carrots (i) in fields, (ii) in greenhouses (iii) soilless (hydroponics) or (iv) in soil?
15. Are there any additional production systems in place in the EU (as well as for imported products)?
16. Which 'bulb and stem vegetables' and carrots can be produced as hydroponic crop?
17. Indicate the major irrigation systems and water sources in the agricultural production of 'bulb and stem vegetables' and carrots.
    Is the water quality controlled (microbiologically)? If so and if available, provide data on microbiological quality of the water used in the agricultural production of 'bulb and stem vegetables' and carrots.

PROCESSING OF BULB AND STEM VEGETABLES AND CARROTS

18. Which are the most common processing practices for 'bulb and stem vegetables' and carrots in the EU?
19. Which agricultural practices and processing steps - can be executed (i) only manually, (ii) both manually or mechanically or (iii) preferentially mechanically?
    What are the percentages of manual versus mechanical practices?
20. Indicate the major water sources in the processing of 'bulb and stem vegetables' and carrots.
    Is the water quality controlled (microbiologically)? If so and if available, provide data on microbiological quality of the water used in the processing of 'bulb and stem vegetables' and carrots.
21. How important is the share of production in the EU for different 'bulb and stem vegetables' categories proposed in the scope of the answer to question 1?
    Which proportion of 'bulb and stem vegetables' and carrots are (i) sold directly (without further processing) or (ii) undergoing processing (peeling, pre-cutting, shredding, mixing, packaging and drying)?

DISTRIBUTION AND RETAIL

22. Which are the procedures and conditions for transport and distribution of 'bulb and stem vegetables' and carrots in the EU?
    Are there any specific cooling practices in place for bulb and stem vegetables (e.g. asparagus) at harvest or post-harvest storage (or long distance transport)?
23. Are there any specific control measures in place in the EU to maintain the cold chain during storage and distribution of 'bulb and stem vegetables' and carrots?
    Are there any specific control measures in place to maintain long term storage?
24. Which proportion of 'bulb and stem vegetables' and carrots may be sold without temperature control during distribution in the EU?
25. Describe how traceability of 'bulb and stem vegetables' and carrots is addressed for the different agricultural production systems and processing options?

SYSTEMS IN PLACE TO ENSURE SAFETY OF PRODUCTS

26. Are there any European guidelines/codes available from Freshfel or other associations of producers on practices (including peeling, pre-cutting, shredding, mixing, packaging and drying) to ensure food safety in the production of 'bulb and stem vegetables' and carrots?
27. In your view, what are the strengths and weaknesses of the current GAPs, GMPs and standards to ensure microbiological quality of 'bulb and stem vegetables' and carrots?
28. In your view, which are the major weak points from the microbiological point of view in the agricultural production systems as well as in the processing of 'bulb and stem vegetables' and carrots?
29. Do the producers of peeled/pre-cut/shredded/mixed/pre-packaged/dry 'bulb and stem vegetables' and carrots in the EU need to be registered as food processing establishments?
30. What are the hygienic requisites that these processing establishments need to comply with?
    How is compliance with these hygienic requisites verified?
31. Are there any central repositories of data on non-compliance with the GAPs, GMPs, standards as well as on the analysis of these data?

32. Are there many companies producing 'bulb and stem vegetables' and carrots which are applying the "test to release" for microbiological parameters? If so, are companies using presence/absence tests? In case enumeration testing is used, which are the threshold levels (cfu/g) used for interpretation of the analysis results?
33. Are the producers, producer associations or any other stakeholders (e.g. retail) also doing regular testing/monitoring of 'bulb and stem vegetables' and carrots?
34. Which are the sampling plans used in the scope of this testing/monitoring of 'bulb and stem vegetables' and carrots?
35. Is there any additional testing/monitoring in place for imported 'bulb and stem vegetables' and carrots?
36. Does Freshfel have any available data in the EU on levels of detection and enumeration of *Salmonella, Yersinia, Shigella* and Norovirus in 'bulb and stem vegetables' and carrots?
37. Which methods for detection and enumeration of *Salmonella, Yersinia, Shigella* and Norovirus in 'bulb and stem vegetables' and carrots are being used in the food chain in the EU?
38. Which are the differences on the hygienic requisites for the production of organic 'bulb and stem vegetables' and carrots when compared to conventional production?
    How is compliance with these hygienic requisites verified?
39. What are the hygienic requisites in place for imported 'bulb and stem vegetables' and carrots?
    How is compliance with these hygienic requisites verified?
40. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of soil, substrates, manure or compost?
41. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of water (reservoirs, irrigation systems, processing water)?
42. Describe the practices in use in the EU for chemical and/or physical decontamination of 'bulb and stem vegetables' and carrots? Which are the main methods in place in the EU?
43. Which chemical and/or physical decontamination methods are allowed in the EU among Member States?
44. Does Freshfel provide specific recommendations on methods used to reduce contamination of 'bulb and stem vegetables' and carrots by *Salmonella*, *Yersinia*, *Shigella* and Norovirus?

6 June 2014

Background information bulb & stem vegetables and carrots

Opinion EFSA-Q-2012-00176

Definitions (questions 1-2)

(1)Categorisation

A. Production

No specific categorisation

B. Processing

Fresh

- Non-packed or packed without processing
- Dried and packed (e.g. onion, shallot, garlic)
- Washed and packed in trays (e.g. asparagus, carrots)

Fresh-cut

- Trimmed
- Peeled
- Chopped
- Shredded

C. Retail presentation

Fresh

- Loose in the shelf, either in wooden crates, plastic crates or cardboard
- Plastic bags, mesh bags or trays

Fresh-cut

- Snacks
- Crudités (e.g. shredded carrots)
- Stir-fry mixes
- Soup mixes

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(2) Varieties

The following botanical varieties are commonly used:

A. Bulb vegetables

Allium cepa L. Cepa (onion) (see also breakdown in powerpoint presentation)

=> yellow, red, white – dried products

=> green onions/spring onions – fresh products

Allium oschaninii O. Fedtsch. (shallot)

Allium sativum var. sativum L. (garlic)

B. Stem vegetables

Asparagus officinalis L. (asparagus) => white, violet, violet/green, green

Apium graveolens var. dulce (Mill.) Pers. (ribbed celery)

Foeniculum vulgare var. azoricum (Mill.) Thell. (fennel)

Allium porrum L. (leek)

C. Carrots (Daucus carota L.) => Nantaise, industry varieties (see also breakdown in powerpoint presentation)

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EU market (questions 3-11, 21)

(10) Detailed statistics have been prepared for the main products constituting the bulb and stem vegetables and carrot categories. The data provided relate to the production in the EU, imports from 3rd countries and intra-EU import flows for each product. Production data have been obtained from FAOSTAT, whereas trade data have been obtained from EUROSTAT. It should be noted that these data do not distinct product flows going to the fresh market from product flows going to processing (canned/frozen vegetables).

(5-7) Bulb and stem vegetables and carrots on the EU market are pre-dominantly produced in the EU and the share of imports from 3rd countries is limited. The main EU producing countries for **bulb vegetables** are France, Germany, Italy, the Netherlands, Poland, Romania, Spain and UK, while 3rd countries supply 5% of onions (New Zealand, Egypt, Australia) and 22% of garlic (China, Argentina). The main EU producing countries for **stem vegetables** are Belgium, France, Germany, Italy, the Netherlands, Poland, Spain and UK, while 3rd countries supply less than 1% with the exception of asparagus (12%, mainly Peru). The main EU producing countries for **carrots** are Belgium France, Germany, Italy, the Netherlands, Poland, Romania, Spain and UK, while 3rd countries (Israel, Turkey) supply only 1,5%.

(3-4) The most important bulb and stem vegetables and carrots are as follows: onions (6 mln T), carrots (5,5 mln T), leeks (850.000 T), celeriac (350.000 T), shallots (295.000 T) garlic (280.000 T), white asparagus (170.000 T), kohlrabi (110.000 T) and green asparagus (90.000 T, mainly ES and IT). No detailed figures are available for the other products. As the share of imports from 3rd countries is limited (except for asparagus and garlic), this overview generally corresponds with the importance of the product categories in sales. Generally, the main volumes of onions, celeriac and kohlrabi will go to the processing industry, as well as substantial volumes of asparagus and carrots.

(11 and 21) There are no detailed statistics available on the share of production of bulb and stem vegetables and carrots sold directly or undergoing processing. Based on more detailed information per variety, about 1/3 of the carrot acreage is destined for industry. With regard to onions about 10% of the supply in the Netherlands is destined for industry.

(9) With regard to the differentiation between commercial production and home or small-scale production, there are no reliable figures available. Whereas home or small-scale production of vegetables is by and large considered as marginal in Western Europe, it is more prevalent in certain Eastern European countries. The economic crisis and certain trends (local produce, authenticity) may however have contributed to an increased popularity of the segment.

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Agricultural production systems (questions 12-17)

(12, 14-15) The bulb and stem vegetables and carrots categories are generally grown in fields, in soil. There are no survey results describing how bulb and stem vegetables and carrots are produced in the EU.

(16) The major irrigation systems used in agricultural production are sprinkler irrigation. The main water sources include surface waters (river, lake), reservoirs supplied by well water or rain water, and well water. In the case of products destined for the fresh market, the water quality is mostly controlled just once per year. In the case of products destined for the fresh-cut market, a control plan is required. A water assessment of each farm determines the microbiological testing frequency according to the production system, type of crop, water source, irrigation system, ... In general E. Coli, Salmonella, Streptococcus faecalis, and total coliforms are the parameters being analysed.

Typically onions do not require irrigation, as they are quite resistant to drought stress. Less than 5% of the surface is irrigated. Carrots do however require excellent water availability for quality reasons and irrigation availability is generally a necessity, especially with sowing and harvesting.

(13) The field staff in the production of bulb and stem vegetables and carrots are mainly seasonal workers from various countries depending on the production countries, although growing and harvest operations are largely mechanised. In the packinghouse, there's a mix between national and foreign workers. The workers are trained with regard to the prevention of food safety incidents, which is generally a prerequisite in certification schemes (e.g. GlobalGAP) and national guidelines.

Processing (questions 18-20)

(17) The processing practices in the fresh-cut segment include quality inspection of the raw materials, cleaning (dry brushing to remove soil), peeling (abrasive peeking/knives) and/or cutting and/or grading, cleaning, rinsing, drying, packing (under modified air/atmosphere). All processes take place under regulated temperature to ensure the maintenance of the cold chain.

(18) The harvest of bulb and stem vegetables and carrots is generally taking place mechanically. Cutting, grading and packing can be done both manually and mechanically, whereas peeling, cleaning, rinsing and drying are carried out mechanically. It is estimated 60% of practices in the fresh-cut operations are carried out manually.

(19) The main water sources used in the processing practices are drinking water and potable well water. The water is tested according the applicable microbiological standards for potable water.

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Distribution & retail (questions 21)

(21) No particular transport and distribution conditions apply for products destined for fresh market (i.e. transport under ambient temperature), for quality reasons many operators will nevertheless try to ensure the cold chain, particular for long haul transport (<10°C). In the case of fresh-cut, transport and distribution need to take place under regulated temperature. The practices vary per country and are fixed in national legislation (BE, DE, NL: <7°C, FR: 1-4°C, IT: <6°C, SE: 2-5°C). In general operators will apply lower temperatures to optimise quality and shelf life.

In the case of long term storage carrots are stored at 1°C with a relative humidity of 95% in cold stores or in soil. Onions are generally stored in bulk or wooden crates in ventilated stores at ambient temperature with a relative humidity of 30-40% to ensure optimal drying conditions, if needed complemented with heaters. The products can be stored from harvest till May/June.

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Enjoy Fresh
Fruits & Vegetables

19 July 2013

Background information distribution & food safety practices

Distribution & retail (questions 21-24)

(21) No particular transport and distribution conditions apply for leafy greens destined for fresh market (i.e. transport under ambient temperature), for quality reasons many operators will nevertheless try to ensure the cold chain, particular for long haul transport (<10°C). In the case of fresh-cut, transport and distribution need to take place under regulated temperature. The practices vary per country and are fixed in national legislation (BE, DE, NL: <7°C, FR: 1-4°C, IT: <6°C, SE: 2-5°C). In general operators will apply lower temperatures to optimise quality and shelf life. Some species (e.g. herbs),however, do not support such lower temperatures.

(22) The control of the cold chain will be under the responsibility of the manufacturer until the delivery, whereby the temperature will be checked during loading and unloading of the truck as well as being registered during transport. From delivery until the purchase by the consumer, the control of the cold chain will be under the responsibility of the retailer. In the case of long term storage (e.g. cabbage, carrots, onions), cabbage and carrots are stored in cold stores whereby temperature and moisture are set. Onions are stored similarly to potatoes in ventilated cold stores whereby sprout suppressants are used.

(23) All vegetables for the fresh market may be sold under ambient temperature. In general most vegetables will however be sold under regulated temperature to maintain quality and ensure longer shelf life. Fresh-cut produce may only be sold under regulated temperature (see also question 21).

(24) Traceability: see presentation

Food safety systems (questions 25-42)

(25-26) Guidelines for good hygiene practices in fresh produce are available at national level, with separate guidance for primary production, distribution & trade as well as processing (fresh-cut). All guidance documents are generic and apply to both fruit and vegetables, although they include specific provisions for certain product categories where needed.

EU guidelines are not available, private certification systems (e.g. GlobalGAP, QS, IFS, BRC, ...) however provide a broader scope.

The main strength of these schemes consists in the identification of hazards and establishment of preventive measures from field to distribution. A weakness in the guidelines on primary production is the lack of attention to microbiological and emerging risks. These are however gradually being addressed.

(27) Major weak points in agricultural production system include the irrigation with surface

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water, contamination by pests or animals and contact with the soil for certain salad types. The principal weak point for fresh-cut produce is a possible major rupture of the cold chain after delivery.

(28) EU Hygiene rules (Reg. 852/2004) require the registration as food processing establishment of any company producing fresh-cut produce. The hygienic requirements these companies need to comply with are provided in Annex II which are further clarified in national good hygiene practices guidelines or private certification schemes. Control of these requirements take place through control plans, internal and external audits as well as official inspections.

(29) There is no central repository of non-compliances at EU or national level. Generally companies analyse non-compliances in order to improve their practices. Some national industry associations pool microbiological test results on fresh produce as well as chlorine data to enable collective improvement actions or monitor the state of play regarding pathogens for which no microbiological criteria have been established.

(30) Positive release schemes are not used in the fresh-cut segment given the short shelf life of fresh-cut produce and the time needed for microbiological analysis.

(31) Producers and producer associations do carry out regular testing, a microbiological control plan is defined by each party involved in primary production. A retail level a random control plan is implemented.

(32) Sampling plans for microbiological testing/monitoring are defined in the legislation and are set by each food business operator on the basis of a risk analysis.

(33 and 37-38) Imported produce is treated similarly to EU produce and is not subject to additional testing or specific other hygiene requirements.

(34) Freshfel does not have centralised data available regarding the detection of Salmonella and Norovirus on leafy greens, or Salmonella, Yersinia, Shigella and Norovirus on bulb and stem vegetables and carrots.

The French fresh-cut industry association (SFPAE) collected data for Salmonella on leafy greens, from 2010 to 2012 more than 1.000 samples per year (all negative). The association is also carrying out further research regarding norovirus (results expected in 2014).

Belgium, Germany and the Netherlands have set-up a monitoring scheme for various fruit and vegetables which will be implemented in the coming months.

(35) Detection methods being used:

- Salmonella: NEN-EN-ISO 6579:2002, BRD 07/11-12/05, Rapid Salmo AES 10/4-05/04
- Norovirus: no validated method to date (research French association SFPAE)
- Shigella: NEN-EN-ISO 21567:2004
- Yersinia: NEN-EN-ISO 10273:2003

Commercial kits are sporadically used, generally companies prefer accredited methods in order to avoid discussions in case of complaints.
Commonly vegetables in the fresh-cut segment are tested on Salmonella, E. Coli and Listeria; other pathogens may be tested for on specific request of customers.

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(36) There is no difference in hygienic requirements for the production of organic versus conventional leafy greens.

(39) Decontamination methods used in primary production:

- Soil treatment: Metam-sodium, Dazomet, 1,3-Dichloropropone, steam, solarisation
- Manure treatment: composting

These treatments are primarily meant to combat pests (nematicide) and disease, and limit weed competition (herbicide). Assurance schemes generally recommend to maximise the time between manure application and harvest. GlobalGAP recommends untreated organic fertiliser should not be used from 60 days previous to the harvest season.

(40) Water treatment methods:

- Water reservoir: mostly no treatment, where allowed oxidative or copper compounds as well as chlorine
- Irrigation system: chlorydric acid
- Processing water
  - Chemical: chlorine solutions; ozone; peracetic acid
  - Physical: UV-light, ultrasound

(41) Decontamination methods of produce:

- Chemical: not available
- Physical: grading (optical and visual), recovery of foreign bodies by difference in density in the cleaning trays, leaching during the cleaning process, rinsing with drinking water

(42) Freshfel does not provide specific recommendations on methods used to reduce contamination by pathogens on fresh produce.

Key differences EU vs US fresh produce practices

- Preventive approach (GAP, GHP) EU versus curative approach US => disinfection in the field and of finished product
- Production concentrated in South West => transportation time =>longer shelf life (14-18 days vs 7-11 days in EU)
- Processing facilities near the production sites in US vs processing facilities nearby the consumer market in EU
- Transport under regulated temperature in EU vs transport with crushed ice (source of contamination) in US
- Presence of large cattle farms with flood washing systems nearby rivers which are used for irrigation in US
- Scale of operators is much larger in US vs EU
- Larger market penetration of fresh-cut produce in US vs EU

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Appendix B. Bulb and stem vegetables and carrots production statistics tables (EUROSTAT, FAOSTAT) (provided by Freshfel on 19 August 2014

Table 8: Onion production in metric tons (Source: FAOSTAT)

Producing Country	2007	2008	2009	2010	2011	Share in 2011
Netherlands	1 117 000	1 269 362	1 303 755	1 337 060	1 577 877	21.9 %
Spain	1 218 528	1 100 540	1 304 120	1 151 900	1 394 804	19.3 %
Poland	752 468	618 233	707 792	577 983	676 956	9.4 %
Germany	428 058	464 405	505 640	447 077	581 324	8.1 %
France	229 830	194 594	227 724	387 908	499 500	6.9 %
Italy	371 452	403 521	384 418	380 855	413 793	5.7 %
Romania	324 993	395 579	378 106	369 142	394 305	5.5 %
Extra EU	443 779	383 758	272 692	309 424	333 717	4.6 %
United Kingdom	323 950	364 550	368 800	378 900	315 700	4.4 %
Greece	188 630	224 400	218 607	212 292	267 649	3.7 %
Austria	97 620	122 608	139 428	154 104	200 497	2.8 %
Portugal	120 500	126 100	127 300	132 915	117 721	1.6 %
Belgium	66 200	72 700	78 300	82 319	76 376	1.1 %
Denmark	55 000	55 800	54 628	52 270	62 940	0.9 %
Hungary	70 333	69 789	63 154	42 676	59 118	0.8 %
Czech Republic	40 424	41 505	38 765	34 653	45 631	0.6 %
Sweden	28 000	30 000	33 084	31 500	41 623	0.6 %
Slovakia	22 662	28 544	26 394	28 222	35 743	0.5 %
Finland	22 918	20 602	21 883	19 991	24 754	0.3 %
Lithuania	17 578	29 582	20 574	19 034	24 189	0.3 %
Bulgaria	16 813	22 395	14 473	25 446	22 437	0.3 %
Latvia	16 687	17 270	29 799	16 292	20 200	0.3 %
Ireland	8 700	10 056	10 295	10 094	9 244	0.1 %
Malta	6 537	6 475	7 645	8 478	7 981	0.1 %
Slovenia	4 520	5 343	5 997	4 667	6 333	0.1 %
Estonia	1 353	2 440	1 914	2 155	1 301	0.0 %
Luxembourg	92	66	81	40	75	0.0 %
Cyprus	78	75	70	70	71	0.0 %
Total	**5 994 703**	**6 080 292**	**6 345 438**	**6 217 467**	**7 211 859**	**100.0 %**

Table 9: Onion import from intra-EU in metric tons (Source: EUROSTAT)

Importing country	2007	2008	2009	2010	2011	2012	Share in 2012
United Kingdom	265 134	272 186	280 563	281 692	278 345	252 788	21.1 %
Germany	210 492	218 031	198 699	240 287	222 079	178 145	14.8 %
Belgium	110 695	121 596	114 941	110 518	116 526	118 232	9.9 %
France	105 163	109 996	93 303	86 928	84 408	99 606	8.3 %
Netherlands	72 198	65 552	118 950	88 273	92 935	82 445	6.9 %
Italy	51 684	56 444	62 378	58 321	52 387	56 981	4.7 %
Poland	69 868	78 531	50 629	106 840	84 472	55 974	4.7 %
Czech Republic	59 452	56 591	59 489	60 399	56 689	52 545	4.4 %
Portugal	43 707	36 244	35 880	36 674	37 671	45 286	3.8 %
Spain	26 358	52 746	58 880	41 881	36 116	34 984	2.9 %
Romania	11 226	17 834	19 114	17 370	24 760	33 223	2.8 %
Sweden	30 731	22 212	24 727	29 606	31 367	32 091	2.7 %
Ireland	34 952	45 405	31 724	32 989	31 388	28 886	2.4 %
Slovakia	17 287	19 474	16 527	18 239	23 655	17 407	1.5 %
Austria	19 835	23 147	22 832	25 018	19 442	14 734	1.2 %
Lithuania	11 020	15 324	11 176	14 420	16 127	13 840	1.2 %
Slovenia	10 810	13 261	13 458	12 723	12 438	12 476	1.0 %
Bulgaria	1 283	774	4 915	7 245	10 108	12 039	1.0 %
Denmark	10 547	11 281	11 877	14 182	13 129	11 381	0.9 %
Finland	6 041	5 773	7 373	6 061	9 217	11 346	0.9 %
Hungary	14 631	13 573	17 829	14 621	12 145	10 258	0.9 %
Latvia	4 055	6 289	6 416	8 375	6 895	8 234	0.7 %
Estonia	3 824	4 600	6 560	6 893	6 141	5 830	0.5 %
Cyprus	675	1 797	2 438	2 982	3 578	4 093	0.3 %
Greece	4 186	6 711	7 715	6 447	5 672	3 191	0.3 %
Luxembourg	1 553	1 593	1 450	3 640	3 374	3 102	0.3 %
Malta	512	895	734	338	590	754	0.1 %
Total	**1 197 919**	**1 277 860**	**1 280 577**	**1 332 962**	**1 291 654**	**1 199 871**	**100.0 %**

Table 10: Onion import from extra-EU in metric tons (Source: EUROSTAT)

Exporting Country	2007	2008	2009	2010	2011	2012	Share in 2012
New Zealand	109 914	115 476	88 073	90 921	70 803	77 259	31.5 %
Egypt	63 943	47 104	36 325	62 961	73 644	53 197	21.7 %
Australia	35 917	37 441	33 806	32 973	39 899	38 915	15.9 %
Chile	35 259	43 500	24 153	47 563	57 514	20 775	8.5 %
Mexico	8 220	10 951	14 000	8 808	12 747	11 669	4.8 %
India	9 318	16 298	11 056	13 994	11 805	10 945	4.5 %
Peru	2 254	3 219	2 320	3 689	5 090	6 919	2.8 %
Macedonia	5 814	2 223	1 070	1 453	3 600	6 157	2.5 %
Argentina	52 710	28 203	29 839	10 731	22 313	4 441	1.8 %
Turkey	58 438	46 057	10 089	14 695	13 924	3 103	1.3 %
Others	61 992	33 286	21 961	21 636	22 378	12 090	4.9 %
Total	**443 779**	**383 758**	**272 692**	**309 424**	**333 717**	**245 470**	**100.0 %**

Table 11: Garlic production in metric tons (Source: FAOSTAT)

Producing Country	2007	2008	2009	2010	2011	Share in 2011
Spain	151 674	133 610	154 000	136 561	139 882	38.3 %
Extra-EU	93 082	84 015	77 625	73 188	81 997	22.5 %
Romania	49 948	72 333	63 245	67 215	66 602	18.2 %
Italy	28 800	26 958	26 403	29 655	30 585	8.4 %
France	20 447	19 673	20 148	17 933	19 403	5.3 %
Greece	10 459	10 700	10 000	9 500	10 500	2.9 %
Hungary	5 156	4 685	4 399	4 171	6 466	1.8 %
Slovakia	2 772	2 129	2 121	2 141	2 223	0.6 %
Lithuania	2 728	2 862	2 916	1 790	1 796	0.5 %
Portugal	1 800	1 860	1 900	1 984	1 757	0.5 %
Bulgaria	1 197	1 153	1 555	2 263	1 665	0.5 %
Malta	438	552	659	516	537	0.1 %
Austria	222	276	263	308	483	0.1 %
Slovenia	254	301	307	292	449	0.1 %
Czech Republic	2 038	1 759	210	222	322	0.1 %
Estonia	178	165	74	110	167	0.0 %
Latvia	828	145	66	118	144	0.0 %
Cyprus	191	163	154	155	141	0.0 %
Finland	22	16	12	17	32	0.0 %
Total	**372 234**	**363 355**	**366 057**	**348 139**	**365 151**	**100.0 %**

Table 12: Garlic import from intra-EU in metric tons (Source: EUROSTAT)

Importing country	2007	2008	2009	2010	2011	2012	Share in 2012
Italy	17 287	16 677	19 569	20 758	23 989	22 684	19.5 %
Germany	16 155	15 257	16 659	17 322	16 818	17 575	15.1 %
France	15 321	12 028	11 958	14 489	14 133	14 587	12.6 %
Portugal	7 599	7 332	7 389	7 616	7 138	11 182	9.6 %
United Kingdom	14 381	12 385	10 934	11 138	17 268	9 724	8.4 %
Czech Republic	5 515	4 812	5 025	4 836	5 223	6 980	6.0 %
Belgium	2 632	2 730	2 906	3 376	3 649	4 699	4.0 %
Austria	3 573	4 243	4 120	4 107	3 918	3 839	3.3 %
Netherlands	4 165	3 488	4 398	3 392	4 136	3 699	3.2 %
Spain	3 253	3 865	2 867	2 566	3 583	3 397	2.9 %
Poland	3 009	3 115	3 282	3 067	2 164	2 793	2.4 %
Sweden	2 557	2 437	2 419	2 486	3 258	2 669	2.3 %
Slovakia	2 404	2 658	2 183	1 636	1 737	2 018	1.7 %
Romania	452	549	554	573	1 309	1 405	1.2 %
Lithuania	825	908	1 227	1 574	1 551	1 334	1.1 %
Ireland	1 357	2 174	1 120	1 144	1 114	1 333	1.1 %
Hungary	176	399	559	814	589	1 054	0.9 %
Slovenia	652	937	1 260	963	699	821	0.7 %
Greece	1 285	1 141	1 096	1 030	1 234	791	0.7 %
Finland	895	994	958	868	808	790	0.7 %
Latvia	631	620	677	631	659	737	0.6 %
Denmark	1 274	1 240	1 092	651	724	658	0.6 %
Bulgaria	315	378	421	509	681	508	0.4 %
Estonia	373	296	377	346	315	302	0.3 %
Luxembourg	340	312	278	291	269	266	0.2 %
Cyprus	100	84	125	141	219	140	0.1 %
Malta	176	235	193	105	195	92	0.1 %
Total	**106 702**	**101 294**	**103 646**	**106 429**	**117 380**	**116 077**	**100.0 %**

Table 13: Garlic import from extra-EU in metric tons (Source: EUROSTAT)

Exporting Country	2007	2008	2009	2010	2011	2012	Share in 2012
China	63 853	56 795	51 569	48 270	53 145	42 982	60.6 %
Argentina	18 209	19 331	19 035	17 450	17 344	16 330	23.0 %
Egypt	3 551	2 637	2 388	2 348	4 217	4 790	6.8 %
Chile	1 714	1 272	1 755	1 711	3 066	3 217	4.5 %
Mexico	1 962	2 219	2 009	2 424	2 881	3 153	4.4 %
USA	535	210	153	239	377	174	0.2 %
Brazil	1 032	447	88	-	149	72	0.1 %
Turkey	86	79	73	470	185	51	0.1 %
Zimbabwe	26	10	7	9	12	29	0.0 %
India	572	1	5	-	3	29	0.0 %
Tunisia	2	16	29	7	1	23	0.0 %
Morocco	409	250	60	117	412	23	0.0 %
Peru	24	123	42	44	-	22	0.0 %
Madagascar	10	16	16	24	13	11	0.0 %
Other	1 096	611	395	74	192	19	0.0 %
Total	**93 081**	**84 017**	**77 624**	**73 187**	**81 997**	**70 925**	**100.0 %**

Table 14: Carrot production in metric tons (Source: FAOSTAT)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2012
Poland	938 230	817 024	913 304	764 585	887 374	834 698	15.2 %
United Kingdom	752 277	719 270	718 700	763 100	694 104	663 700	12.1 %
Germany	562 296	547 073	570 239	553 972	533 717	592 761	10.8 %
France	312 612	301 495	636 469	601 904	624 459	544 979	9.9 %
Netherlands	543 000	496 000	561 000	481 000	482 000	511 000	9.3 %
Italy	565 300	594 800	523 330	489 171	542 691	482 302	8.8 %
Spain	426 074	414 517	420 000	424 300	268 100	377 400	6.9 %
Belgium	269 800	288 900	326 100	314 100	317 400	317 400	5.8 %
Romania	185 094	234 752	215 346	221 082	245 508	200 475	3.6 %
Portugal	150 000	154 000	156 000	162 881	144 262	150 000	2.7 %
Sweden	89 400	91 600	122 600	83 000	104 870	128 700	2.3 %
Austria	74 246	80 849	83 587	85 631	109 044	98 272	1.8 %
Extra-EU	53 945	58 657	108 744	85 475	76 622	93 371	1.7 %
Denmark	70 000	67 299	91 590	104 830	107 240	84 858	1.5 %
Hungary	119 200	75 151	65 628	58 532	65 149	74 721	1.4 %
Lithuania	62 712	56 973	63 716	40 895	70 478	67 800	1.2 %
Finland	68 351	60 751	70 608	67 509	72 758	55 751	1.0 %
Greece	43 619	47 600	45 000	43 600	54 800	53 300	1.0 %
Slovakia	31 817	37 155	35 654	34 879	42 005	42 005	0.8 %
Latvia	30 408	36 446	43 317	34 307	38 632	28 082	0.5 %
Ireland	25 582	24 595	26 021	25 588	25 503	27 000	0.5 %
Czech Republic	39 466	34 406	22 333	18 834	24 390	20 763	0.4 %
Estonia	20 126	15 556	20 885	22 817	24 517	17 083	0.3 %
Croatia	11 553	7 629	10 954	12 999	10 767	15 294	0.3 %
Bulgaria	10 286	13 437	14 614	10 576	11 997	9 590	0.2 %
Cyprus	1 879	1 899	2 145	1 988	3 254	3 364	0.1 %
Slovenia	2 530	3 280	3 897	2 039	2 974	2 709	0.0 %
Malta	1 450	1 129	1 060	1 365	1 327	981	0.0 %
Luxembourg	203	310	409	478	231	230	0.0 %
Total	**5 461 456**	**5 282 553**	**5 873 250**	**5 511 437**	**5 586 173**	**5 498 589**	**100.0 %**

Table 15: Carrot import from intra-EU in metric tons (Source: EUROSTAT)

Importing country	2007	2008	2009	2010	2011	2012	Share in 2012
Belgium	269 469	301 779	275 932	256 494	276 268	278 629	29.4 %
Germany	198 599	242 126	189 145	231 569	210 168	217 684	23.0 %
France	112 786	112 091	121 525	116 270	113 131	131 353	13.9 %
Netherlands	34 273	33 564	39 302	30 154	30 392	36 424	3.8 %
Czech Republic	37 314	34 899	37 547	40 135	37 947	36 104	3.8 %
United Kingdom	49 347	46 800	45 883	29 537	32 465	31 339	3.3 %
Portugal	39 801	26 289	22 793	32 910	29 028	28 890	3.0 %
Poland	29 422	42 499	36 457	37 680	40 965	27 366	2.9 %
Ireland	15 935	16 179	19 296	17 150	18 597	19 472	2.1 %
Slovakia	17 765	18 653	15 526	16 977	20 587	18 515	2.0 %
Austria	13 929	20 639	15 483	22 679	20 634	16 297	1.7 %
Romania	7 645	12 368	7 553	9 063	11 197	14 003	1.5 %
Spain	30 807	17 934	13 360	23 341	16 380	13 953	1.5 %
Sweden	13 059	13 784	8 120	7 537	6 597	13 576	1.4 %
Denmark	9 144	10 080	12 276	10 205	8 110	11 343	1.2 %
Lithuania	8 006	15 214	9 613	13 019	11 478	8 296	0.9 %
Hungary	13 594	12 153	11 123	12 445	9 911	7 161	0.8 %
Slovenia	5 123	6 522	5 970	6 182	6 675	6 508	0.7 %
Italy	4 742	7 701	8 401	4 927	5 096	6 011	0.6 %
Latvia	2 988	4 182	5 559	4 094	4 099	5 583	0.6 %
Finland	5 923	6 972	8 114	5 159	4 791	5 449	0.6 %
Luxembourg	2 787	2 553	1 515	4 045	4 136	3 904	0.4 %
Bulgaria	886	512	2 074	3 056	2 198	3 089	0.3 %
Greece	3 639	3 500	3 522	3 464	4 144	2 949	0.3 %
Cyprus	278	289	467	1 586	1 742	1 479	0.2 %
Estonia	1 510	1 500	2 607	1 675	1 316	1 378	0.1 %
Malta	655	1 124	1 284	555	685	527	0.1 %
Total	**929 426**	**1 011 906**	**920 447**	**941 908**	**928 737**	**947 282**	**100.0 %**

Table 16: Carrot import from extra-EU in metric tons (Source: EUROSTAT)

Exporting country	2007	2008	2009	2010	2011	2012	2013	Share in 2013
Israel	11 867	18 086	59 310	42 222	35 457	64 080	66 737	73.4 %
Turkey	34 248	31 970	36 088	33 857	32 114	20 856	14 660	16.1 %
USA	1 386	2 174	2 721	2 907	3 094	2 942	3 395	3.7 %
China	682	625	2 845	2 496	2 530	2 605	2 484	2.7 %
Costa Rica	794	794	395	592	610	1 046	1 491	1.6 %
Mexico	-	-	92	-	-	169	594	0.7 %
South Africa	588	957	300	259	513	636	560	0.6 %
Australia	2 982	2 183	2 608	2 136	961	562	392	0.4 %
Other	784	1 504	3 551	264	680	173	324	0.4 %
Serbia	28	51	164	105	366	214	178	0.2 %
Morocco	586	313	671	637	297	90	81	0.1 %
Total	**53 945**	**58 657**	**108 745**	**85 475**	**76 622**	**93 373**	**90 896**	**100.0 %**

GLOSSARY

Bulbs are storage organs for biennial plants and thus they must survive a winter period. They are formed by modified, fleshy leaves rich in nutrients (scales), surrounding a bud from which the plant will grow after the winter period. They have evolved various protective measures including the formation of dry external tunics, the biosynthesis of natural products, which act as feeding deterrents for insects and small mammals as well as antimicrobial agents. The Alliums including onions, shallots, garlic and leeks fall into this class (Hanson, 2011).The Onion and shallot bulb contain one single bud, whereas the garlic bulb is a complex bulb consisting of several small bulbs (also called garlic cloves), each containing one bud.

Carrots (*Daucus carota* L.) are biannuals root vegetables of the *Apiaceae* family. The edible portion is the storage taproot, which contains high levels of carbohydrates (sugars) and ß-carotene (pre-vitamin A). In general, high quality carrots are firm, straight from "shoulder" to "tip," smooth with little residual "hairiness," sweet with no bitter or harsh taste, and show no signs of cracking or sprouting (Suslow et al., 2002).

Celery (*Apium graveolens* L.) is a biennial stem vegetable from the *Apiaceae* family but is planted and harvested as an annual crop. The edible portion is the long, thick, green fleshy petioles and, if present after trimming, associated leaves. High quality celery consists of stalks which are well formed, have thick petioles, are compact (not significantly bowed or bulging), have minimal petiole twisting, and have a light green and fresh appearance (Suslow and Cantwell, 1998).

Clean water is clean seawater (natural, artificial or purified seawater or brackish water that does not contain micro-organisms, harmful substances or toxic marine plankton in quantities capable of directly or indirectly affecting the health quality of food) and fresh water of a similar quality (Regulation (EC) No 852/2004).[27]

Decontamination treatments are mechanical, physical, and chemical treatments, which are applied to eliminate contaminants, including microbial contamination. They can be applied to water, surfaces, equipment and areas.

Disinfectants are agents or systems that kill or eliminate bacteria found on inanimate surfaces or environments. Within this opinion, disinfectant agents or systems are defined as those decontamination agents applied to eliminate micro-organisms in wash water.

Garlic (*Allium sativum* L.), is a member of the onion family (*Amaryllidaceae*). It is a bulb comprised of cloves (thickened storage leaves) individually wrapped in dried leaf sheaths or skins attached to a compressed stem plate. The whole bulb is also wrapped in several layers of dried leaf sheaths. Garlic is produced as an annual crop for seed, fresh market, and processed products. High quality garlic bulbs are clean, white (or other colour typical of the cultivar), and well cured (dried neck and outer skins). The cloves should be firm to the touch. Cloves from mature bulbs should have a high dry weight and soluble solids content (SSC) – more than 35 % in both cases (Cantwell, 2014).

Green onions/spring onions, also called spring onions or scallions, are onions (*Allium cepa* L.), which are eaten for their immature bulb and green foliage (Adamicki, 2014). Green onions lack a fully developed root bulb and have a relatively mild onion flavour. For more information see "Onions".

Fertigation is the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system.

[27] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.

Food of non-animal origin include those derived from plants and comprise a wide range of fruit, vegetables, salads, juices, seeds, nuts, cereals, herbs, spices, fungi and algae, which are commonly consumed in a variety of forms. Categorisation of FoNAO, as considered in the scope of this scientific opinion, is discussed in Section 2.2 of EFSA Panel on Biological Hazards (BIOHAZ) (2013b).

Food Safety Criteria are defined in EU legislation for the microbiological acceptability of food products and are criteria defining the acceptability of a product or a batch of foodstuff applicable to products placed on the market (Regulation (EC) No 2073/2005).[28] If a Food Safety Criterion is not met for a product or batch of foodstuff, then this should not be placed on the market or, if it already has, be considered for recall.

Fresh Produce refers to fresh fruits and vegetables that are likely to be sold to consumers in an unprocessed or minimally processed (i.e. raw) form and are generally considered as perishable. Fresh produce may be intact, such as strawberries, whole carrots, radishes, and fresh market tomatoes, or cut during harvesting, such as celery, broccoli, and cauliflower.[29] In the scope of this opinion fresh produce also applies to fresh-cut produce, such as pre-cut, packaged, ready-to-eat salad mixes.

Fungicide is a specific type of pesticide that controls fungal diseases by specifically inhibiting or killing the fungus or fungal spores.

Good Agricultural Practices (GAP) apply available knowledge to address environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products (FAO, 2003).

Good Hygiene Practices (GHP) relate to general, basic conditions for hygienic production of a foodstuff, including requirements for hygienic design, construction and operation of the plant, hygienic construction and use of equipment, scheduled maintenance and cleaning, and personnel training and hygiene. A developed and implemented GHP programme is a pre-requisite for HACCP system (EFSA, 2005).

Good Manufacturing Practices (GMP) cover the principles needed to design plant layout, equipment and procedures for the production of safe food. This includes hygienic operation and cleaning and disinfection procedures. The codes and requirements may be formally specified by e.g. Codex Alimentarius Committee on Food Hygiene (EFSA, 2005).

Harvest is the process of collecting mature crops from the fields and immediate handling.

Hydro-cooling is one of several post-harvest cooling methods available to growers, packers, and shippers to reduce the temperature of the crops. This technique consist in dumping produce into cold water, or running cold water over produce to remove heat.

Hydro-coolers produce chilled water and then move this water into contact with the produce.

Hygiene Criteria are criteria indicating the acceptable functioning at pre-harvest, harvest and on farm post-harvest production prior to processing and are proposed to verify and validate Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP).

Minimal processing is any action applied to the initial product (e.g. cleaning, coring, peeling, chopping, slicing or dicing and washing) and which is not included below in the definition of processing (e.g. heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a

[28] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p.1-26.

[29] FDA Guidance for Industry: guide to minimize microbial food safety hazards for fresh fruits and vegetables. 1998. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ProducePlantProducts/ucm064574.htm

combination of those processes). Minimal processing may occur at harvest as well as on farm post-harvest and at processing.

Onions (*Allium cepa* L.) are biennial plants of the *Alliaceae* family. The edible portions of the bulb are the enlarged leaf bases and compact stem. Green onions, also called scallions, are eaten for their immature bulb and green foliage. The predominant flavour component results from activity of the enzyme alliinase in broken or crushed tissue, yielding the volatiles propyl disulphide and methyl propyl disulphide. High quality onions should have mature bulbs with good firmness and compactness of fleshy scales. The size, shape and colour of the dry skin should be typical for the cultivar. They should be free of mechanical or insect damage, decay, sunscald injury, greening of fleshy scales, sprouting, bruising and any other defects (Adamicki, 2014).

Pesticides cover insecticides, acaricides, herbicides, fungicides, plant growth regulators, rodenticides, biocides and veterinary medicines. Pesticides are chemical compounds: a substance or mixture of substances, or micro-organisms including viruses used in plant protection to: (i) kill, repel or control pests to protect crops before and after harvest; (ii) influence the life processes of plants; (iii) destroy weeds or prevent their growth; (iv) preserve plant products.[30]

Petiole is the slender stalk that attaches the leaf blade to the stem. Through evolution, the petiole comes from the differentiation of the leaf blade and is histologically different from the stem. In some plant species the leaves are directly attached to the stem without petiole (e.g. onion), while in others the petiole in particularly developed (e.g. celery).

Potable water is water which meets the requirements laid down in Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (mainly microbiological and chemical criteria) (Regulation (EC) No 852/2004).[31]

Post-harvest is the stage of crop production after harvest and includes on-farm cooling, cleaning, sorting and packing.

Pre-harvest incorporates all activities on the farm that occur before crop products are harvested.

Process Hygiene Criteria are criteria indicating the acceptable functioning of the production process. Such criteria are not applicable to products placed on the market. They set an indicative contamination value above which corrective actions are required in order to maintain the hygiene of the process in compliance with food law (Regulation (EC) No 2073/2005).[32]

Processing are any actions that substantially alter the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes (Regulation (EC) No 852/2004).[33]

Salad bar is a buffet-style table or counter sometimes at a restaurant or in a retail establishment, although this can also be in a specific food provider. Salad components are provided for assembly, sometimes by the customers themselves. In addition to ready-to-eat salad and other foods of non-animal origin (including fruit and pulses), ready-to-eat meat, fish, egg products as well as bread and cooked pasta may be available together with salad dressing.

[30] Based upon definition available at http://ec.europa.eu/food/plant/plant_protection_products/index_en.htm
[31] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.
[32] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p.1-26.
[33] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.

Sanitizers are chemical agents that reduce micro-organisms on food contact surfaces by at least 99.999 %. Within this opinion sanitizers are defined as those decontamination agents applied to reduce the level of micro-organisms on bulb and stem vegetables and carrots.

Scales modified fleshy leaves that form concentric fleshy layers that form the bulbs. Onions are formed by layered scales, which are the bases of the leaves of the onion plant that swell to accumulate water and nutrients while the onion bulb matures and the upper part of the leave dries. The external, dry, scales of the onion bulb are called tunics and protect the bulb from dehydration. Garlic is formed by scaly scales which are modified leaves loosely clustered around the stem base.

Shoots are sprouts obtained from the germination and the development of seeds, or from the development of buds. Depending on their development, shoots may correspond to enlarged buds, young stem, young leaves, and cotyledons - the latter only in the case of sprouts from seeds.

Stem is the main trunk of a plant, the primary plant axis that develops buds and shoots.

Stem plate is a flat and very short stem at the basis of the onion bulb that carry the scales (bases of the leaves) and on which the roots are attached.

Stems vegetables are plants grown for the whole stems which are used as vegetables, e.g. asparagus, celery and rhubarb.